

PB85-207876

Impact of Suspect Hazard Designation on
Chemical Use and Activity: A Pilot Study

Heiden Associates, Inc., Washington, DC

Prepared for

Environmental Protection Agency, Washington, DC

May 85



U.S. Department of Commerce
National Technical Information Service

NTIS

EPA Report Number 560/4-85-003
May 1985

IMPACT OF SUSPECT HAZARD
DESIGNATION ON CHEMICAL USE
AND ACTIVITY: A PILOT STUDY

by

Edward V. Heiden and Mark E. Eads

Contract No. 68-01-6630
Subcontract 24055-02

Debra Harper
Project Officer
Economics and Technology Division
Office of Toxic Substances
Washington, DC 20460

OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

REPORT DOCUMENTATION PAGE		1. REPORT NO. EPA 560/4-85-003	2.	3. Recipient's Accession No. PB85 207876/AS
4. Title and Subtitle Impact of Suspect Hazard Designation on Chemical Use and Activity: A Pilot Study				5. Report Date April 30, 1985
7. Author(s) Edward V. Heiden and Mark E. Eads				6.
9. Performing Organization Name and Address Heiden Associates, Inc. 1815 H Street, NW Suite 501 Washington, DC 20006				8. Performing Organization Rept. No.
12. Sponsoring Organization Name and Address Economics and Technology Division, Office of Toxic Substances (TS-779) Environmental Protection Agency 401 M Street, SW Washington, DC 20460				10. Project/Task/Work Unit No. 24055-02
				11. Contract(C) or Grant(G) No. (C) 68-01-6630 (G)
				13. Type of Report & Period Covered Final Report
15. Supplementary Notes				14.
16. Abstract (Limit: 200 words)				
How chemical firms regulated by EPA respond when their products are designated as suspect toxic hazards (as distinguished from being formally regulated) was the subject of a pilot study to: (1) determine the types of public data and methodological approaches available to study the problem; and (2) assess and measure actual impact based on (1). Ten chemicals were selected for initial study, based on: (1) their presence on NIOSH and EPA or OSHA lists of potential carcinogenic substances; (2) availability of sufficient public data for analysis (3) reasonable diversity and representativeness. A total of 28 categories of production or use were studied for these ten chemicals. There were supplemented by eight uses for three additional chemicals in some of the analyses conducted. Economic case history studies and formal econometric statistical models were the investigation tools used. It was concluded that although important data gaps and limitations in economic methodology existed in this pilot study, sufficient public data were available for a number of high-profile chemicals to conduct a meaningful pilot assessment of the impact of suspect hazard designation on their production/use, and that for these chemicals suspect hazard designation frequently had a significant impact on production/consumption.				
17. Document Analysis a. Descriptors				
Economic impact	Impact on production	Acrylonitrile	Chromium Compounds	
Toxic Substances	Impact on consumption/use	Arsenic	Formaldehyde	
Potential carcinogen	Econometric modeling	Benzidine Based Dyes	Nickel and Nickel Compounds	
	Chemical case studies	Cadmium	Perchloroethylene	
		Chlorofluorocarbons	Trichloroethylene	
b. Identifiers/Open-Ended Terms				
c. COSATI Field/Group				
18. Availability Statement Release unlimited		19. Security Class (This Report) Unclassified	21. No. of Pages	
		20. Security Class (This Page) Unclassified	22. Price	

ACKNOWLEDGMENT

We wish to acknowledge with gratitude the many helpful comments and suggestions we have received on earlier drafts and concepts for this report from Ms. Debra Harper, Contract Officer, Office of Toxic Substances (OTS); Mr. Sammy Ng, Section Head, Section 2, Regulatory Impacts, ETD, OTS; and Dr. Michael Shapiro, Acting Deputy Director, ETD, OTS.

We would also like to express special thanks to the HQ and OTS library staff of the Environmental Protection Agency and to Mr. Daniel Marsick, Technical Data Center, Occupational Safety and Health Administration.

In addition, we wish to thank Dr. Robert Trost of George Washington University for his contributions to the econometric modeling section of this report.

Any errors, omissions, or other failures, of course, are the authors own.

TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
A. Methodology Used	4
B. Scope, Objectives, and Limitations of Study	9
II. INDIVIDUAL REPORTS FOR TEN CHEMICAL SUBSTANCES	12
1. Acrylonitrile	20
2. Arsenic	41
3. Benzidine-Based Dyes	63
4. Cadmium	82
5. Chlorofluorocarbons (CFCs)	103
6. Chromium Compounds	127
7. Formaldehyde	152
8. Nickel and Nickel Compounds	169
9. Perchloroethylene (PERC)	191
10. Trichloroethylene (TCE)	200
III. ECONOMETRIC ANALYSIS	215
A. Individual Statistical Modelling for Ten Chemicals and 25 Chemical Uses/Activities	215
B. Pooled Cross Section Time Series Model	230
C. Results of the Pooled Cross Section Time Series Model with Eight Additional Chemical Uses Included	236
D. Summary and Conclusions	247
APPENDIX A	
APPENDIX B	
APPENDIX C	
REFERENCES	

EXECUTIVE SUMMARY

In February of 1983, Heiden Associates, Inc. (formerly Heiden, Pittaway Associates, Inc.) was engaged by the Office of Toxic Substances of the Environmental Protection Agency (EPA) to conduct a pilot assessment on the question of how chemical firms that are regulated by EPA respond to the designation of one or more of their chemical products as suspect toxic hazard(s). Such designation is to be distinguished from, and in almost all instances, precedes formal regulation. It is accomplished by means of one or more of the following: (1) appearance on a designated chemicals list or in the form of a notice; (2) appearance on a testing schedule; (3) general expression of agency concern in the absence of listing; or (4) a proposed rulemaking notice or advance notice. Until now, the question has not been the subject of systematic study, and industry response mechanisms to suspect hazard designation thus are not widely understood. While it would be expected that firms would curtail their production or consumption of chemicals designated as suspect toxic hazards for fear of such consequences as the threat of potential non-marketability through adverse publicity, product liability exposure, or other causes, the nature and extent of firms' responses would be expected to depend on a variety of factors—such as degree of expected hazard, availability and price of substitutes, and other factors.

This pilot study was designed to: (1) determine the types of data which existed in the public domain and the types of methodologies which could be developed to assess the impact of designating a chemical as a suspect hazard in its production and/or in one or more of its major uses; and (2) to provide a preliminary scoping assessment and measurement of impact, to the extent that data and methodological considerations of (1) permitted.

Ten chemicals were selected for initial study, based on three factors:

- Documentation that a chemical had been the subject of health, safety, or environmental concern through its presence on lists of potential carcinogenic chemicals prepared by NIOSH and on either EPA or OSHA sublists derived from master NIOSH lists.

- Availability of sufficient public economic and regulatory data for analysis purposes. In this connection, chemicals where data availability could not be easily determined through initial search and inquiry were not considered for inclusion.
- Reasonable diversity and variety of the total sample in terms of salient characteristics, such as volume and kind of use, availability of substitutes, nature of the chemical—organic or inorganic; degree of public attention to regulatory issues involving the chemical; and number of manufacturers.

For these ten chemicals, it was determined that sufficient data existed in the public domain to conduct pilot analyses for 28 applicable categories of production and/or use in order to illuminate the issue of the existence and possible impact of suspect hazard designation on industry consumption or production. These ten chemicals and their 28 uses were:

- **Acrylonitrile**
 - a. Production
 - b. Fibers
 - c. Resins
 - d. Elastomers
- **Arsenic**
 - a. Refining
 - b. Herbicides
 - c. Industrial (Wood Preservatives)
- **Benzidine-Based Dyes**
 - a. Benzidine
 - b. Benzidine-Based Dyes
 - c. Specific Dyes (Direct Black 38 and Direct Brown 95)
 - d. Consumer Dyes
- **Cadmium**
 - a. Refining
 - b. Pigments
 - c. Plating
- **Chlorofluorocarbons (CFCs)**
 - a. Aerosols
 - b. Non-aerosols
- **Chromium Compounds**
 - a. Cr(VI) Compound Production
 - b. Pigments

- c. Metal Treatment
- d. Leather Tanning
- **Formaldehyde**
 - a. UF Foam Insulation
 - b. Chelating Agents
- **Nickel and Nickel Compounds**
 - a. Refining
 - b. Alloys
 - c. Nickel Compound Production
 - d. Electroplating
- **Perchloroethylene (PERC)**
 - a. Dry Cleaning
- **Trichloroethylene (TCE)**
 - a. Metal Degreasing

Three types of analyses were conducted during the pilot study to test the consistency, reliability and quality of the data. Where the data proved useable, preliminary assessments of impact were then conducted. The three types of analyses were:

1. Development of detailed narrative suspect hazard, regulatory, and economic histories and statistical data profiles for each of ten chemicals and 28 activities/uses, based on inspection of a variety of relevant public data sources and analysis of data from those sources.
2. Development of formal statistical models for each of the activities/uses for which data were available in order to identify and distinguish the impact of suspect hazard designation from other relevant regulatory and economic variables on a chemical-specific basis. Variables modelled included: price of substitutes; general level of economic activity; feedstock supply conditions; demand for major output products where the chemical was used; existence and timing of suspect hazard and formal regulatory events.
3. Development of a series of preliminary statistical models on a pooled basis for all data-available activities/uses in order to test the aggregate (as distinguished from chemical-specific) relationship between suspect hazard designation and industry behavior. These models included as variables all of those of (2), and in addition, attempted to assess the impact of other

potentially significant variables such as time lags, media publicity, and degree of involvement of the regulatory agency in the actual suspect hazard designation. Data were pooled on a cross-section, time-series basis, using such standard statistical techniques as ordinary least squares (OLS), analysis of covariance (ANCOVA), and least squares dummy variable (LSDV) analysis. Several alternative model specifications were tested, based on alternative assumptions about how many suspect hazard and regulatory events were applicable to each chemical. Once initial development was accomplished, these models were further tested by also including data for eight activities/uses of three additional chemicals beyond the original ten, for a total of 33 activities/uses analyzed.

Findings and Conclusions

1. Data in the public domain are indeed available for a large number of high-profile chemical activities and uses in a way that is helpful for investigating the impact of suspect hazard designation on chemical consumption/activity trends.

2. Such public data yield generally consistent findings between the two types of uses to which they were put, i.e., the ten economic history case studies and the formal statistical models. However, these public data—though generally consistent—had limited value in enabling definitive conclusions to be made concerning the impact of suspect hazard designation. There were three significant reasons for this:

- a. Important data gaps existed for potentially critical variables other than suspect hazard designation, such as frequent lack of data to assess: (1) the price and feasibility of substitutes; (2) the role of technological change on supply costs; (3) the role of other regulatory influences that could be occurring in the same time frame as suspect hazard designation, e.g., state and local requirements, or formal regulations of other agencies; (4) behavior for time periods prior to 1970 and after 1980/81; and (5) the significance of imports. In some cases, these gaps could be overcome with additional time and resources; in others, the gaps were inherent in the data—e.g., price series which were simply not available or applicable.

- b. Econometric models for pilot testing purposes were specified as simply as possible, and resource limitations prevented the use of more refined econometric modelling techniques to further test certain initially promising relationships that had been discovered.
- c. Suspect hazard status was sometimes difficult to determine, because of incomplete or inconsistent records on such elements as, for example: publication of research findings or their effective dates; date of first interest by relevant regulatory agency; or potentially relevant state/local activity.

3. Even though data and methodological approaches were limited in the ways indicated above, application of the case study and economic modelling frameworks to the high-profile chemical activities/uses described above, revealed that suspect hazard designation did appear in many instances to have some noticeable and potentially significant negative impact on the level of chemical production/consumption, as expected.

Results of the case history studies for the ten chemicals and their uses/activities showed the following:

- For 14 of the 28 chemical activities/uses studied, suspect hazard designation had some negative impact on production activity or consumption trends, though in many cases this impact was difficult to separate from the impact of other variables.
- For eight of the 28 studied cases, the case history data did not provide a clear indication of the separate impact of suspect hazard designation.
- For the remaining six cases, suspect hazard designation did not appear to be associated with declining production/consumption impact.

Econometric modelling for 25 of 28 chemical-specific activities/uses for which sufficient statistical data were available generally (though not always) reinforced results based on the case study analysis. In nine of 13 data-available cases where case study analysis had indicated negative impact for suspect hazard designation, formal statistical modelling corroborated the negative production/

consumption impact finding for at least one of the suspect hazard events examined (without contradicting it for others). In only one of the four remaining cases did the statistical analysis actually point in the opposite direction to indicate positive impact; in the other three it was inconclusive. In six of eight instances where case study data did not reveal any discernible impact of suspect hazard designation, the formal statistical analysis showed agreement. In the two remaining cases, it pointed to an unexpected positive impact. In three of four data-available cases showing unexpected positive or no dampening impact of suspect hazard designation, the statistical model corroborated the analysis. In the remaining case, the statistical model showed a strong finding in the expected (negative) direction. It should be noted that two chemical uses showing unexpected positive impact—formaldehyde chelating agents and chromium leather tanning—were particularly limited in the amount and quality of available public data.

Subject to the qualifications described above, the use of pooled (aggregate) econometric modelling techniques did permit some preliminary generalizations about the trends which were found on the chemical-specific statistical and case study bases described above. These trends, based on the initial 25 cases, were reinforced by adding public data for eight additional chemical uses, which indicated the consistency of these results using public data. Keeping in mind the limitations described above that were applicable to the public data base, as well as the fact that general findings based on the pooled econometric data apply only to a base of 33 high-profile chemicals rather than to the population of chemicals-in-general, these results are both interesting and somewhat surprising. They suggest many potential avenues for further analysis. These pilot findings can be summarized as follows:

- Suspect hazard events appeared generally to have an important impact on consumption, one that was statistically significant (at the 10% significance level or greater) for certain of the events. After the first suspect hazard event, firms appeared to show a tendency to increase consumption temporarily by drawing down inventories, then to reduce it substantially after the inventory drawdown.

- Suspect hazard designation appeared to affect consumption for specific chemical uses much more than it did general production of a chemical. Moreover, its effect on consumption for specific uses was, on the average, almost as great as that of formal regulation.
- When a suspect hazard designation was accompanied by extensive media publicity, it tended to intensify the impact on consumption—both the immediate impact of temporarily increased consumption through initial drawdown of inventory as well as the subsequent reduction of consumption afterwards.
- The impact of suspect hazard designation on consumption/use was not significantly different when lagged a year rather than tested as a simultaneous event. Introduction of a one-year lag period, however, resulted in the disappearance of the inventory-drawdown-induced increase in consumption after the first suspect hazard event.
- Based on the simple, preliminary modelling results, suspect hazard events appeared to dampen consumption/production of chemicals to a greater extent when they were characterized by federal engagement than when they involved non-federal action (e.g., an academic or private sector study).
- Economic variables—feedstock supply, general level of activity, price of substitutes—did not appear to play as significant a role in explaining changes in consumption as did suspect hazard and regulatory events. This conclusion, however, requires especially cautious interpretation because of the lack of substantial economic data and resource constraints which prevented more complete specification and testing of the models used.

I. INTRODUCTION

In the academic regulatory literature (as well as in previous studies conducted by Heiden Associates, Inc. and other economic consulting firms), a phenomenon has been observed that can cause industry to respond quickly to adverse information about a chemical substance, and to act even in the absence of a regulation to reduce or eliminate the amount of that substance in the marketplace. That phenomenon usually results from a pre-regulatory event and, in particular, the designation by a agency of a substance as a suspect toxic hazard, either through appearance on a list or a notice, or informal appearance on a testing schedule. Other pre-regulatory events such as announced federal agency concern or proposed rulemaking would also precipitate this phenomenon. Such suspect toxic hazard designation can take one of several forms: findings of potential carcinogenicity, teratogenicity, mutagenicity, and other acute or chronic health effects. This designation of a chemical as a suspect hazard is to be distinguished from the act of formal regulation itself, whose impact on consumption and producer cost/ activity has been and continues to be the subject of widespread study. Indeed, estimation of the economic impact of major formal regulatory initiatives is now a required step in the federal regulatory process.

The nature, extent, or determinants of this behavior are not clearly understood. The following types of activities can be noted:

- Withdrawal by a user to prevent being caught with a large inventory of product which could become unmarketable;
- Withdrawal for one use leading to a domino effect causing more complete withdrawal by the manufacturer;
- Withdrawal from use for fear of adverse publicity about a company or product;
- Withdrawal from use to avoid potential product liability exposure;
- Continued use because of low public exposure and a lack of available substitutes;
- Acceleration of a declining market growth (use) curve; and

- Responsible companies seeking to avoid unnecessary hazards associated with production/consumption of chemical.

Withdrawal of a substance designated as suspect has both positive and negative attributes. If the substance is later found to be a significant toxic hazard, early withdrawal or reduction in use is a general benefit. Conversely, if the substance is later found to be free of hazard, or free of hazard in the specific applications or use, then foregone public and industry economic benefits can occur.

There are several potential secondary effects of marketplace withdrawal as well. If the substance were an intermediate or ingredient in a final product, then performance or utility of that final product could be degraded, or the final product could be eliminated altogether if adequate substitutes were not available. Product costs could increase from the use of substitutes. On the assumption that the use of a substance in a product represents a balance between cost and utility, given the availability of substitutes, then the use of a higher cost substitute could in fact lead to a superior product.

It was felt that a formal study of this largely unexplored suspect hazard designation phenomenon would have several benefits. First, such a study would enable a regulatory agency to examine the consequences of suspect hazard designation on marketplace behavior as well as specific industry actions in response to the listing (e.g., cooperation, challenge, delay, etc.). An ability to know and understand the real motivations behind an industry reaction could enable an agency to handle a suspect hazard designation issue more effectively and secure an improved level of industry cooperation or regulation. Second, such a study could also demonstrate the value of early potential toxic designation for those substances which should be removed from the marketplace as early as possible. Third, such a study could provide the knowledge that a federal regulatory agency would need to determine the effectiveness of notification on rate of removal. An agency such as EPA would be able to predict removal actions from knowledge of factors such as nature of use and availability of substitutes, based on information which can be obtained from the literature. Fourth, such a study could become the basis for modeling the impact of suspect hazard

designation on the availability and use of the substance. Such a predictive model would permit one to potentially forecast in specific quantitative terms:

- The rate of market withdrawal
- The effect on substitute demand
- The reaction of manufacturers
- The reaction of product users

In an attempt to obtain greater insight into the phenomenon of suspect hazard designation and its impact on chemical production and use, the Environmental Protection Agency (EPA) in April, 1983, commissioned Heiden Associates, Inc. to undertake a pilot study to determine whether data and a methodology could be developed to assess the economic impact of designation of a substance as potentially toxic. Specifically, this pilot study was designed to determine the feasibility of using primarily public and other secondary data sources such as EPA contractor reports to answer questions such as the following:

- Does listing or designation of a substance as a potential suspect hazard lead to reduced use or withdrawal of the substance from the market?
- Does the method or form in which a substance is designated as a potential toxic hazard impact market behavior? (i.e. pre-regulation vs. regulation)
- What are the determining factors which lead to such behavior, or inhibit such behavior?
- How is the phenomena of reduced use or withdrawal associated with specific kinds of uses or types of substances?
- What kinds of secondary effects does such behavior cause, such as elimination of a particular kind of product or increase in demand for substitute materials?
- Does a reduced demand lead to a price decrease which causes the designated substance to become a substitute for another substance, but with lower exposure potential?
- How does the size of the market, number and nature of end users of the substance, size of product inventories, avail-

ability and price of substitutes, influence manufacturer/user/consumer reaction to the designation?

The pilot was also designed to provide initial estimates of actual suspect hazard designation impact as well, for the chemical studied, to the extent that this proved feasible.

This report presents the results of our pilot effort. The report is divided into four sections. First is this introduction which describes the methodology used. The second section consists of detailed studies of the impact of suspect hazard designation for each of ten chemicals that were initially selected for this pilot study, and summaries of key findings for each chemical. In the third section, we report on our preliminary efforts to develop a formal econometric modeling framework for examining in a more rigorous quantitative manner the impact of suspect hazard designation on each of 25 use and activity categories for the ten chemicals initially examined, as well as on all categories taken together. Fourth, we extend the econometric analysis to include eight new chemical uses or activities involving four additional chemicals, for a total of 33 chemical uses and activities. Finally, in the last section, we report on steps needed to translate this pilot study into a full-scale impact assessment study.

A. METHODOLOGY USED

The methodology employed in this pilot study consisted of selection of suitable chemicals for study, based on determination that sufficient economic and regulatory data were available for each chemical to conduct a meaningful assessment.

It was initially determined that a sample of approximately ten to fifteen chemicals would be appropriate for pilot investigation purposes. The following criteria were employed:

- Volume of production, both high and low, with the meaning of "high and low" being defined relative to the use made of the substance, i.e., use as a surfactant or lube oil additive, or dye, or commodity industrial chemical, etc.
- Category of use, such as surfactant, dye, etc.
- Potential for human exposure in the intended use.
- Competition and availability of substitutes in the intended use
- An approximately equal number of inorganic and organic chemical substances
- Inclusion of at least a few chemicals where suspect hazard designation had not been subject to significant public attention.

The starting point for sample selection was the use of three lists compiled by federal agencies of potential carcinogenic substances. These lists were compiled by agencies to inform the public that a suspect hazard determination had been made either through public or private efforts with respect to a given substance. The most comprehensive list is that of NIOSH, consisting of approximately 3,000 potentially carcinogenic substances, published in 1976. In addition, two federal agencies with direct regulatory responsibilities also published separate suspect toxic substances lists. These consisted of subsets of the NIOSH list representing chemicals of particular interest to these agencies. OSHA, as part of its worker exposure concern, published its list in 1980. EPA in the same year released its carcinogen assessment group list. These two lists, largely dealing with different chemicals, embody the high level of federal regulatory attention to a substantial group of chemical substances.

We used these EPA and OSHA subset lists, drawn from the NIOSH list, for selection of an initial sample group of substances for this study. Knowing that most data sources do not publish production/consumption data for which there were fewer than three manufactureres/importers (because of proprietary considerations), the study focused only on those candidate substances for which there were three known current manufacturers. With this initial "shopping list," a

search was made for data on those candidate substances within publicly available data sources (Predicasts Basebook, Kirk-Othmer Encyclopedia of Chemical Technology, etc.).

Because so few substances in this sample group turned out to have three current manufacturers (some substances have been phased-out of production or banned), those publicly available data sources were again checked to find candidate substances for which there were production/consumption data for earlier years, coinciding with the year of first scientific designation of suspect hazard status. This exercise produced a subset of substances for which information was publicly available. From this list of final candidate substances, and in consultation with the EPA project officer, a final selection was made of chemicals for use in this study based on the additional criterion of production volume.

No chemical was entered into the target population for potential selection from the EPA and OSHA lists unless several types of data existed. These consisted of:

- Data on the nature of principal uses of materials consumed in significant quantities.
- Data enabling construction of product flow patterns for tracking consumption in the principal uses and use of potential substitute materials.
- Time series of production and sales data that were as recent as possible. Timeliness in production and sales data was needed because suspect hazard designation is a relatively recent phenomenon for almost all chemical uses and activities.
- Data on activity levels for the general economy, competition from substitute substances in producing end products, competition between end products, etc. These data were necessary to isolate those explanatory factors which had independent and potentially significant impact in addition to the impact of suspect hazard designation.
- Detailed history data on regulatory and pre-regulatory events.

The analytic procedure used consisted of several steps. First, based on the criteria stated above, ten chemicals were selected initially for development of detailed regulatory and economic histories applicable to study of the impact of suspect hazard designation. Data elements for each of the ten chemicals included:

- Production data
- Production/consumption or products in which used
- Output product
- Historical profile of suspect hazard designation
- Historical profile of regulation
- Feedstock supply
- Relative price
- General economic factors, such as significance of imports or changes in level of existing inventory.

Second, formal reports were prepared on principal activity/use categories applicable to each of the ten chemicals initially selected. Most chemicals were characterized by multiple activities and uses. Twenty-eight activity/use categories applicable to these ten chemicals were selected for analysis. The purpose of these reports was to show graphically and by direct inspection of relevant data series, the extent to which suspect hazard designation made a difference in overall level of activity (consumption or production). For many individual chemical uses and activities, it was possible to observe impacts (declines) on consumption/production over time that appeared to be directly associated with designation of that use or activity as a suspect hazard, and to consider at least to some extent, whether general economic factors may also have made their own contribution to the impacts observed.

Third, the historical data for these ten chemicals were placed within a formal analytic framework using econometric modelling techniques to study suspect hazard impact. It was felt that such a systematic framework would allow more careful consideration of the relative roles played by each potential relevant explanatory factor. Consequently, a model was developed, as follows:

Consumption/production over time was a function of:

- Suspect hazard status. Each suspect hazard event in the chemical's history was counted as a potential explanatory factor.
- Regulatory status. Each actual regulation by any health and safety agency was counted as a potential explanatory factor.
- Demand for the output product in which the chemical was used.
- Supply conditions for feedstocks.
- General level of economic activity.
- Price of substitutes.

The model was then tested with available quantitative data developed for each of 28 uses/activities applicable to these ten chemicals.

Fourth, the data from 25 of these 28 chemical activities and uses were then pooled into one large data set in order to statistically test a pilot model of the aggregate relationship between suspect hazard designation and consumption/output, taking into account all other factors in the model that might also have influenced consumption/output. For three uses, sufficient public data were not available in an adequate quantitative format to permit such testing. These were: arsenic, nickel refining, and chromium (VI) compound production.

Fifth, the pilot model was extended by developing data on eight uses/activities applicable to three additional chemicals which fit the selection criteria stated above, and a new pooled statistical analysis was then performed on the resulting total of 33 chemical uses.

The first two steps are encompassed in Chapter II, which presents the reports on each of ten chemicals initially selected as meeting data availability criteria and summarizes findings for each of the 28 uses/activities applicable to these chemicals.

Chapter III presents the third, fourth, and fifth steps of the analysis. It describes in detail the formal analytic framework employed to study suspect hazard impact for the ten chemicals selected, and presents results of the individual statistical analyses of each chemical as well as the results of pooling chemical activities/uses into one large data set.

It then describes results of the pooled statistical model using an extended data base consisting of three additional chemicals beyond the original ten—for a total of 33 uses/activities. Results of the pooled analysis are then summarized based on the initial results described.

Last, Chapter IV indicates additional steps which would be required to develop this pilot analysis into a full-scale model of the impact of suspect hazard designation.

B. SCOPE, OBJECTIVES, AND LIMITATIONS OF STUDY

It is important to emphasize again at the outset that this study represents a pilot effort. As a pilot, its purpose was not to build a formal, full-scale model to test the impact of designation of a chemical as a suspect hazard. Rather, the principal objective was much more limited. It was to determine whether data were available in the public domain in a form which could be used or made usable to test the relationship for individual chemicals between changes in consumption/production and suspect hazard designation as well as the other factors influencing consumption/production—formal regulations themselves and economic and technological variables. If it was found that such data were not available, determination of the impact of suspect hazard designation would make it necessary to go outside the public domain and conduct direct inquiries of relevant industry members, economic experts, and others, to determine the relevant impacts.

Given this pilot and its limited purpose, the sample frame of chemicals investigated included only those for which the availability of data from public

sources could be relatively easily determined. These tended to be high-profile chemicals that were relatively data-rich. As a result, lesser chemicals were ignored where public data availability could not be so easily determined as a result of initial search and inquiry. For these chemicals—a large number—public data could indeed prove available upon more detailed search.

As will be indicated below, the results of the study show that public data are available for a large number of high-profile chemical activities and uses in a way that is distinctly helpful in indicating that suspect hazard designation may well have some significant explanatory value in accounting for chemical consumption/activity trends. Such public data were available to conduct two types of studies: formal case studies of individual chemicals and—for all but three of the 28 activities/uses for the ten chemicals studied—more formal quantitative modelling using straightforward econometric regression techniques. However, such public data, even though abundant for these chemicals, had only limited explanatory value, whether used in the case study or in the more formal econometric framework. This is because there were a large number of gaps and limitations in the public data which made it impossible to separately evaluate in any definitive way the importance of other explanatory factors besides suspect hazard designation in accounting for changes in chemical use/activity. Among the important limitations were the following:

- Data were not readily available for many chemicals on key potential explanatory variables such as the price or feasibility of substitutes, the role of technological change on supply costs.
- It was not possible in certain cases to fully define and specify other separate but potentially important regulatory events involving the same chemical that were occurring in the same time frame as suspect hazard designation for a given use. For example, certain specific uses of arsenic were being designated suspect hazards at the same time that general regulation of arsenic production was occurring under federal air and water environmental regulation as well as at the state and local levels.
- Public data were available for only a limited number of years—ten for most chemicals, even less for some. Absence of a larger number of observations made it impossible to include all of the

potentially important explanatory variables in certain specifications of our econometric models. For example, the separate impact of large-scale media publicity accompanying suspect hazard designation could only be partially assessed. Likewise, it was impossible to completely test whether federal agency involvement in suspect hazard designation had a separate and significant impact apart from private designation, e.g., an academic research study.

- For two chemical uses—formaldehyde chelating agents and chromium leather tanning—data gaps were particularly numerous. The impacts observed for these uses should be interpreted with particular caution.
- One variable having potential explanatory value—level of imports—could not be modelled at all.
- Certain important variables (such as price series), even when they were available, had to be specified at the generic level of a chemical class rather than a level specific to the chemical use in question.

In addition, resource constraints also operated as a factor limiting the scope and findings of this pilot effort. They prevented a more intensive search for certain types of data (e.g., the price of substitute chemicals). In addition, they restricted us to relatively simple forms of econometric models, and prevented us from conducting alternative experiments with various modelling specifications.

Given these limitations, the positive impact of suspect hazard designation in explaining changes in production/consumption which we found must indeed be regarded merely as preliminary indications of general direction and trend for a data set of high-profile chemicals rather than as actual findings and conclusions applicable chemicals in general. Taken even on the basis however, many of the results are both interesting and surprising, as will be discussed below, and suggest that further inquiry beyond this pilot stage would undoubtedly be fruitful.

II. INDIVIDUAL REPORTS FOR TEN CHEMICAL SUBSTANCES

Individual regulatory impact analyses for each of the ten initial chemicals analyzed are presented in the ten sections that follow. All reports share a common format with a description of trends in consumption and use characteristics, supply factors, and regulatory history for each chemical period. The regulatory analysis which then follows includes an estimation of both pre-regulatory (suspect hazard designation) and regulatory impact for the ten chemicals examined. Because more than one use was examined for eight of the ten chemicals, these ten reports include a total of 28 separate case studies. The following represent the ten chemicals and 28 cases studied:

- **Acrylonitrile**
 - a. Production
 - b. Fibers
 - c. Resins
 - d. Elastomers
- **Arsenic**
 - a. Refining
 - b. Herbicides
 - c. Industrial (Wood Preservatives)
- **Benzidine-Based Dyes**
 - a. Benzidine
 - b. Benzidine-Based Dyes
 - c. Specific Dyes (Direct Black 38 and Direct Brown 95)
 - d. Consumer Dyes
- **Cadmium**
 - a. Refining
 - b. Pigments
 - c. Plating
- **Chlorofluorocarbons (CFCs)**
 - a. Aerosols
 - b. Non-aerosols
- **Chromium Compounds**
 - a. Cr(VI) Compound Production
 - b. Pigments
 - c. Metal Treatment
 - d. Leather Tanning

- **Formaldehyde**
 - a. UF Foam Insulation
 - b. Chelating Agents
- **Nickel and Nickel Compounds**
 - a. Refining
 - b. Alloys
 - c. Nickel Compound Production
 - d. Electroplating
- **Perchloroethylene (PERC)**
 - a. Dry Cleaning
- **Trichloroethylene (TCE)**
 - a. Metal Degreasing

**ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES
IN ACTIVITY/USE FOR 29 CHEMICAL CASES**

SUBSTANCE	CHANGE OBSERVED	EXPLANATORY FACTOR				OTHER ECONOMIC FACTORS	COMMENTS
		CHANGE IN RELATIVE PRICE	PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION			
ACRYLONITRILE							
a. Production	Acrylonitrile production steadily increased	Yes. Introduction of the Sohio process decreased costs in the early 1960s	Not known. Cannot be separated from impact of economic/technological factors	Not known. Cannot be separated from impact of economic/technological factors. Government economic study predicted little impact in case of one regulation	Yes New process catalysts, oil supply disruptions, and recession	One of two regulatory impacts studied appeared to result in minor added costs of production.	
b. Fibers	Total acrylic fiber production increased. However, relative to some substitutes, it decreased	Yes	Not known. Same as above.	Not known. Same as above.	No	Economic impact of one major regulation was predicted to be relatively minor.	
c. Resins	Both total and relative production with substitutes fluctuated	No. Erratic behavior	Not known. Same as above.	Not known. Same as above.	Yes Inelastic demand for ABS/SAN resins		
d. Elastomers	Absolute production fluctuated but declined relative to all synthetic elastomers	No	Not known. Same as above.	Not known. Same as above.	Yes A rubber strike		
ARSENIC							
a. Refining	Significant decline in production starting in 1970	No	No. Although pre-regulatory designation period coincided other factors were involved (see Comments)	Change underway well before 1978 OSHA standard. Local regulations were also a factor	Compliance with local sulfur dioxide emissions regulations, copper mine strikes, increased imports	Total domestic arsenic supply was declining. Hence, supply constraints might account for all declines observed.	

ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES
IN ACTIVITY/USE FOR 29 CHEMICAL CASES

SUBSTANCE	CHANGE OBSERVED	EXPLANATORY FACTOR			OTHER ECONOMIC FACTORS	COMMENTS
		CHANGE IN RELATIVE PRICE	PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION		
b. Herbicides	Demand declined since 1974 in both absolute and relative terms	Uncertain	Yes. Proposed regulations coincided with decline for all years except 1975	No. Key regulations implemented by early 1970s	No. Arsenic herb. production declined relative to all organic herbicides	Total domestic arsenic supply was declining. Hence, supply constraints might account for all declines observed.
c. Industrial (Wood Preservatives)	Consumption growth was strong during 1970s	Yes	No. Growth began in earnest in year of initial regulatory announcement	Not applicable (no wood preservative regulation exists)	1981 decline associated with housing industry recession	Besides lower costs, arsenical wood preservatives (CCA) have inherent advantages over substitutes
BENZIDINE-BASED DYES						
a. Benzidine	Production and imports decreased to virtually zero levels	Not available. Price of substitutes for key intermediates could, however, be relevant	No.	Yes. Precipitous decline two years after OSHA regulation	No	
b. Benzidine-Based Dyes	Production and imports decreased to virtually zero levels	No. Prices lower than substitutes	Yes. Though impact is difficult to separate from that of regulations	Yes. Decline coincides with OSHA standard	No	
c. Specific Dyes (Direct Black 38 and Direct Brown 95)	Production and imports decreased to virtually zero levels	No. Prices lower than substitutes	Mixed, but overall, indications of impact on change were observed.	Mixed	No	Both dyes declined relative to general category of direct dyes and bbd
d. Consumer Dyes	Production and imports decreased to virtually zero levels	No. Prices lower than substitutes	Yes. Entirely associated with an OSHA health hazard alert and CPSC action on a public petition	No	No	

ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES IN ACTIVITY/USE FOR 29 CHEMICAL CASES

SUBSTANCE	CHANGE OBSERVED	CHANGE IN RELATIVE PRICE	EXPLANATORY FACTOR		OTHER ECONOMIC FACTORS	COMMENTS
			PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION		
CADMIUM						
a. Refining	Declining domestic refinery production displaced by increase in Cd metal imports	No. No cost advantages for imported metal over domestically refined Cd metal	Yes. Change coincided with ANSI standard revisions that formed the basis of the 1974 OSHA dust standard	Mixed. Some gauges coincide with the 1974 OSHA dust standards and 1979 EPA waste-water regulation	No	
b. Pigments	No change. Demand for Cd pigments relative to substitutes and total inorganic pigments remained constant	No. Cd pigment prices higher than substitutes by factor of ten suggest substantial non-substitutability	No. Absence of known Cd pigment regulatory threat or regulation	No pigment hazards and no pigment-specific regulatory threat or regulation	No	
c. Plating	Decrease in relative share of Cd plating to total plating beginning in 1976	No. Generally, the actual cost of metal is a minor factor in total cost of plating	Yes. Change coincided with start of cooperative study on Cd plating pollution and reports on methods of reducing waste water contaminants	Uncertain. Because of the 1982 compliance date for the 1979 EPA waste-water regulation, no assessment can be made	Uncertain. Enhanced Cd waste recovery and recycling may reduce Cd demand	
CHLOROFLUOROCARBONS (CFCs)						
a. Aerosols	Aerosol applications decreased drastically (97%) from 1974-79	No. Inherent consumer advantages of CFCs compared to substitutes overrode any relative substitute price advantages	Yes. Change coincided with publication of CFC-ozone depletion hypothesis	Minor. Major decline occurred before the 1978 CFC ban	Yes. Consumer demand for aerosols diminished	
b. Non-aerosols (refrigeration)	CFC consumption substantially increased (81%) during the 1974-78 pre-regulatory period	No. Inherent consumer advantages of CFCs compared to substitutes overrode any relative substitute price advantages	Yes. Refrigeration applications grew more slowly when it became subject to suspect hazard designation	Not applicable (no regulation implemented)	Yes. General economic and industry-specific trends may have been important to some extent	

**ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES
IN ACTIVITY/USE FOR 29 CHEMICAL CASES**

SUBSTANCE	CHANGE OBSERVED	CHANGE IN RELATIVE PRICE	EXPLANATORY FACTOR			OTHER ECONOMIC FACTORS	COMMENTS
			PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION			
CHROMIUM COMPOUNDS							
a. Cr(VI) Compound Production	Production dipped 10% in 1971, 30% in 1975 and declined 12-15% from 1978 to the present	Not applicable (in aggregate sense)	Yes. 1978 OSHA announcement correlated with decline in that year. Stock reduction (see other economic factors) accounted for only 20% of the 1978 decline	Yes. 1971 OSHA and ANSI standards correlated with decline during that year	Yes. 1975 economic recession appeared to account for 1975 produc- tion decline		
b. Pigments	Decline with 6% dip in 1971, 31% in 1975 and 26% from 1976-80	No. Chromium pigments relatively inexpensive	Yes. 1978 OSHA announcement had impact	Yes. 1971 OSHA and ANSI standards correlated with decline during that year	Yes. The 1975 recession accounted for the decline in that year		
c. Metal Treatment	Consumption declined in 1971, 1973-4, and 1975;	No. Generally, the actual cost of metal is a minor factor in total cost of plating	Mixed. 1973 action appeared to coincide with decline while 1978 OSHA action did not.	Mixed. 1971 and 1976 EPA and OSHA standards correlated with changes in those years. No impact from 1979 EPA action was seen	Yes. The 1975 recession accounted for the decline in that year	Investments in engineering control techniques to recover/recycle wastes might account for changes in later periods. Further investigation needed. Locate regulations may also have been important.	Chromium is primar- ily (though not exclusively) present in the nontoxic form of Cr(III) in leather tannery operations rather than the toxic form of Cr(VI)
d. Leather Tanning	Incomplete Cr(VI) consumption time series seemed to change relatively little	Uncertain. Data incomplete	Uncertain. 1978 OSHA action appeared to correlate with a decline from 1978-81 but time series and often relevant data were incomplete	Uncertain. Data not available	Uncertain. Complete time series needed for estimation		

ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES
IN ACTIVITY/USE FOR 29 CHEMICAL CASES

SUBSTANCE	CHANGE OBSERVED	CHANGE IN RELATIVE PRICE	EXPLANATORY FACTOR		OTHER ECONOMIC FACTORS	COMMENTS
			PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION		
FORMALDEHYDE						
a. UF Foam Insulation	Consumption peaked in 1977 and precipitously declined to zero by 1982	Uncertain. Relative substitute price data not available	Yes. Decline started after wide-spread publicity of health hazard	Yes. However, the CPSC ban occurred in 1982, so that a full estimate is not possible	Not thought to be significant	
b. Chelating Agents	Consumption of NTA declined 40% from 1969-76, then leveled off to 1981	Uncertain. Relative substitute price data not available	Yes. Decline correlated with suspect hazard designation in 1970, 71, 73	Not applicable. (no regulation implemented)	Uncertain. Relative substitute price and supply might also be factors	
NICKEL AND NICKEL COMPOUNDS						
a. Refining	Domestic refining exhibited a secular increase from 1965-81	Not likely. Nickel imports have remained constant although relative price data are not available	No.	No.	Yes. General growth in nickel demand accompanying general economic growth	
b. Alloys	Industry-adjusted consumption for some alloys have declined; others fluctuated but remained relatively constant	Not relevant. Essential use	Not likely. Nickel is an essential component in alloys, especially stainless steel. Regulatory events might have impacted nickel alloy steel, but effect is unclear and may have been cumulative rather than specific to any one regulatory event	Not likely.	Yes. General growth in nickel demand accompanying general economic growth	

ROLE OF POSSIBLE EXPLANATORY FACTORS IN OBSERVED CHANGES
IN ACTIVITY/USE FOR 29 CHEMICAL CASES

SUBSTANCE	CHANGE OBSERVED	EXPLANATORY FACTOR			OTHER ECONOMIC FACTORS	COMMENTS
		CHANGE IN RELATIVE PRICE	PRE-REGULATORY SUSPECT HAZARD EVENTS	REGULATION		
c. Nickel Compound Production	Industry-adjusted consumption of nickel for compounds dipped in 1972 and declined from 1975-79 before increasing to 1981	Not applicable. (in aggregate sense)	Yes. Several events correlated with decline in 1970s. Impact could be cumulative or interactive	Yes. 1971 OSHA standard accounted for 1972 dip, and 1976 standard correlated with decline	Not likely.	
	Industry-adjusted consumption exhibits a secular decline from 1972-80	No. Generally, the actual cost of metal is a minor factor in total cost of plating	Yes. Several events correlated with decline in 1970s. Impact could be cumulative or interactive	Yes. 1971 OSHA standard accounted for 1972 dip, and 1976 standard correlated with decline	Yes. General economic recession in 1975 & 1980 correlate with dips in those years. (see comments)	Changes such as in NI waste recovery/recycling techniques and worker productivity may account for change
PERCHLOROETHYLENE (PERC)						
a. Dry Cleaning	PERC's use in dry cleaning shows a secular decline from a high point in 1973 to 1979, then a large drop in 1980	No. Decrease occurs despite decreasing relative price of PERC to competitor	Yes	Not applicable (no regulation implemented)	No	PERC is a preferred solvent because of non-flammability and other characteristics
TRICHLOROETHYLENE (TCE)						
a. Metal Degreasing	Decreased consumption in metal degreasing application by 50%	No. Relative price changes accounted for only small part of production decline	Yes. Up to 26 of the 50 percentage points of falling production are due to proposed standards	Not significant. Only estimate 1-2% of decline can be explained by regulations	Yes. The general decline in metal degreasing operations accounted for a large share of the production	

SECTION II.1

REGULATORY IMPACT ANALYSIS FOR ACRYLONITRILE

The purpose of this summary is to report on the potential market impact of designating acrylonitrile as a suspect toxic hazard. An estimate of such impact depends on careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. CONSUMPTION AND USE CHARACTERISTICS

Because acrylonitrile (AN) is very reactive and polymerizes readily, it is one of the building blocks of the chemical industry and is used in a wide variety of products with broad consumer distribution. There are four producers of AN in the United States: American Cyanamid, DuPont, Monsanto, and Vistron.

Acrylonitrile gained in importance shortly before World War II, when it was discovered that it could (as a copolymer) greatly increase the resistance of synthetic rubbers to oil and solvents. Since then, a large variety of applications have been developed in the fields of fibers, synthetic resins, elastomers, and as intermediates in organic syntheses. The bulk of acrylonitrile production today goes into three major use areas: acrylic fibers, copolymer resins (plastics), and nitrile rubbers (elastomers). Table 1 shows the changing principal use profile for acrylonitrile.

Table 1. Principal Uses and Consumption of Acrylonitrile

Use	Percent						Apparent Consumption (1981) (mill. lbs.)
	1966	1969	1973	1976	1981 ^e	1983 ^e	
Fibers	63	64	58	50	47	43	938
Resins	19	17	22	20	26	29	519
Elastomers	9	6	6	4	3	3	60
Other (incl. exports)	12	13	14	26	24	25	479
							1996

^e = estimate

Source: Predicasts Basebook (for 1981) and Kirk-Othmer, v. 1, p. 425.

The largest use of acrylonitrile is in production of two types of acrylic fibers. Acrylic fibers of the first type contain at least 85% AN in addition to comonomers such as vinyl acetate, acrylic esters and acrylamide. The second type, called modacrylic fibers, contains 35%-85% AN with a vinyl chloride or vinylidene chloride co-monomer. As a result of their excellent properties and consumer acceptance, acrylic fibers have succeeded in penetrating the traditional markets for woolen apparel and carpeting. Acrylic and modacrylic fibers combined are now produced world-wide and represent the third largest in volume of synthetic fibers produced—behind polyester and nylon. Acrylic fibers are also used in blankets, draperies, upholstery, wigs, man-made furs, handbags, and industrial cloth. There are five manufacturers of acrylic and modacrylic fibers in the United States: DuPont, Monsanto, Eastman Kodak, American Cyanamid, and Dow-Badische (joint venture with BASF of Overzee, N.V., West Germany), (OSHA 1978, p. 2-20).

Acrylonitrile-containing plastics, particularly the resins—acrylonitrile-butadiene-styrene (ABS) and styrene-acrylonitrile (SAN)—constitute the second largest application of acrylonitrile monomer. These resins contain 25%-35% acrylonitrile by weight. Since the introduction of ABS and SAN about 20 years ago, the market has grown at a rapid rate to about 3%-4% of all plastics and resins produced in the United States. There is increasing demand for ABS in engineering-related markets, such as pipe and fittings, automotive parts, appliances, furniture, building components, luggage and packaging, recreational vehicles, and other applications where its mechanical strength, resistance to chemicals and hydrocarbons, and ease of manufacture make it a suitable replacement for many traditional materials. In the United States, eight manufacturers produce ABS and/or SAN resins: Dow Chemical, Abtec, Foster Grant, Monsanto, Hammon, Borg-Warner, Uniroyal, and Rexene Polymers (OSHA 1978, p. 2-33).

As noted above, acrylonitrile imparts hydrocarbon-resistant properties to synthetic rubbers, the third principal use category. Such nitrile rubbers are resistant to chemicals, oils, solvents, heat aging and abrasion, and exhibit good

flexibility at low temperatures. Nitrile rubber is formed by copolymerizing acrylonitrile and butadiene. The higher the proportion of acrylonitrile, the higher the hydrocarbon resistance of the rubber. Since nitrile rubber does not swell or distort when exposed to oil and gas, it is widely used in products likely to come into contact with petroleum products. End uses include oil seals/diaphragms/gaskets, packings, fuel hoses, paper additives, masking tapes, carpet backings, and upholstery coatings. Six domestic manufacturers currently produce nitrile rubber: B.F. Goodrich, Goodyear, Uniroyal, Copolymer, Firestone, and Reichhold (OSHA 1978, p. 2-41). Table 2 provides production time series for acrylic fibers, ABS/SAN resins, and nitrile rubbers.

Table 2. Acrylonitrile Principal Use Production

<u>Year</u>	<u>Acrylic Fibers</u>	<u>Production (mill. lbs.)</u> <u>ABS/SAN Resins</u>	<u>Nitrile Rubber</u>
1965	368.4	NA	130.8
1967	397.7	NA	138.2
1970	491.9	NA	149.8
1971	545.2	758	146.2
1972	625.9	809	164.0
1973	742.1	876	185.9
1974	631.2	856	197.2
1975	524.6	642	121.5
1976	621.0	987	173.2
1977	708.8	1069	161.7
1978	725.7	1134	161.6
1979	761.1	1315	165.8
1980	779.2	1031	144.1
1981	690.8	916	145.9

Source: Predicasts Basebook, pp. 329, 338, 343.

Miscellaneous uses of acrylonitrile are as a chemical feedstock for producing adiponitrile (used as an intermediate in the preparation of nylon 6,6) and acrylamide. It is also used as a pesticide fumigant, as an anti-stall gasoline additive, in the cyano-ethylation of natural fibers (cotton) to improve heat and rot resistance, for nitrile barrier resin containers for use in beverage packaging (banned), and in non-beverage packaging containers (glue, nail polish, correction fluid, air freshener, and blister packages).

B. SUPPLY FACTORS

Acrylonitrile was not used commercially until the late 1920s when German chemists used it to make oil-resistant rubber. Manufacture of AN began in 1940 in the United States. Because of its high price, dictated by the older manufacturing methods, AN production lagged until the late 1960s. The introduction in 1960 of what was known as the Sohio process, a catalytic vapor phase oxidation of propylene and ammonia, utilizing molybdenum or bismuth catalysts, revolutionized the economics of making AN because of the use of less-costly raw materials in the production process.

As a result of the new process, the price of AN declined from 0.53 \$/lb. in 1952 to about 0.14 \$/lb. in 1961. Because of the broad licensing of Sohio's propylene-ammonia process, prices remained relatively constant during the 1960s and reached a low of 0.09 \$/lb. in 1972. These price trends are shown in Table 3. As with other bulk chemicals, raw materials are the major cost factor in producing AN, accounting for 70%-75% of the cost via the Sohio process. The low cost of propylene and ammonia as raw materials substantially reduced the cost of the monomer, thereby stimulating research into new applications for AN. The resulting market development has, in turn, stimulated substantial growth over time in domestic production. Table 3 presents domestic production trends.

Table 3. Production and Price History of Acrylonitrile

<u>Year</u>	<u>Price (\$/lb.)</u>	<u>Domestic Production (mill. lbs.)</u>
1965	0.16	
1966	0.13	771
1967	0.12	716
1968	NA	670
1969	0.12	1021
1970	0.11	1157
1971	0.10	1039
1972	0.09	978
1973	0.11	1115
1974	0.19	1354
1975	0.23	1412
1976	0.24	1215
1977	0.24	1518
1978	0.23	1646
1979	0.24	1752
1980	0.28	2018
1981	0.34	1830
		1996

Source: Predicasts Basebook, p. 383.

It must be noted that imports as a supplement to the domestic supply of AN have been negligible (0-5 percent of total domestic production since 1968).

The future of acrylonitrile is tied to the availability of propylene and ammonia, both of which have been and are expected to be available in sufficient quantities in the foreseeable future.

C. REGULATORY HISTORY

1. Environmental Exposure

Acrylonitrile monomer can enter the environment during the stage of production, waste handling, storage, transportation, use in production of other products, or use of products containing AN.

In the production of AN, emissions can result during several phases of this process, primarily from the absorber vent, flare stack, and storage tanks. Studies have shown such emissions to be about 1/5 or 1/6 the amount of AN emitted during polymer operations.

Potential worker exposure also exists in these polymer operations which constitute the major end uses of AN. In the manufacture of acrylic fibers, exposure potential is greatest during wet-spinning when, after the fibers have coagulated, residual AN is driven-off from the solvent. Potential exposure to acrylonitrile occurs at several points during ABS resin manufacture, including: conveyance of AN from storage tanks; work in the blending, flocculation, and drying areas; and during the process of suspension and solution polymerization. In nitrile rubber manufacture, exposure occurs especially when the polymerization product (with butadiene) is transferred to a tank where residual monomers are stripped. The resulting latex still contains high levels of unreacted monomer, therefore exposure is also likely during the coagulation, washing, and drying processes.

Exposure of the general (non-workplace) population has not been viewed as a significant problem. AN is volatile and reactive and thus would not be expected to persist in the atmosphere. According to OSHA, levels of AN in acrylic fibers are sufficiently low that handling of the fibers has not been viewed as a likely source of AN exposure. Although some migration of AN from ABS/SAN resins has been shown, little migration from finished consumer products has been in evidence according to one study. Exposure potential to AN from two minor uses, AN

barrier resins in food-contact articles and AN-containing home fumigants, has been documented. However, these sources of exposure have been substantially reduced as a result of a ban of AN barrier resin use in beverage bottles and consumer education on the issue of home fumigation. General population contact with AN can also occur, of course, within transportation spills.

2. Nature of Potential Harms and Regulatory Milestones

The biological effects and acute toxicity of acrylonitrile have been extensively documented, beginning in 1942 with collection of mortality data for animal exposure to AN. In 1944, several cases of AN poisoning in workers were reported, followed by more reports of toxic effects of AN in animals in 1947, 1952, 1959, 1961, 1965, 1966, and throughout the 1970s. In 1971, the American Conference of Governmental Industrial Hygienists (ACGIH) recommended a 20 ppm time-weighted average (TWA) occupational exposure limit based on animal exposure data and by analogy with a 10 ppm threshold limit value (TLV)¹ for hydrogen cyanide². Based on this recommendation, OSHA established in the same year a 20 ppm permissible exposure limit (PEL)³ to AN in occupational uses.

¹ Threshold Limit Values (TLVs) refer to air-borne concentrations of substances and represent boundaries below which it is believed that nearly all workers may be repeatedly exposed day after day, without adverse effect. Time-weighted average (TWA) concentrations permit excursions above such a threshold limit, provided they are compensated by equivalent excursions below the limit during an 8-hour work day. Otherwise, TLVs are ceiling limits placing a definite boundary which concentrations should not be permitted to exceed (ACGIH).

² It was previously thought that the toxic action of AN was due to the liberation of cyanide ion, and therefore, resembled HCN poisoning. Although this might be a possible secondary mechanism, there is now considerable evidence that the toxic action of AN is due to its own structure, independent of the liberation of the cyanide ion.

³ Permissible Exposure Limit (PEL) is used by OSHA in specifying worker exposure limits. PEL's usually specify 8-hour time-weighted averages unless otherwise designated as ceiling or threshold limits.

Although AN has long been recognized as a highly toxic substance, evidence of its carcinogenic, mutagenic, and teratogenic effects is relatively recent. In March 1977, Dow Chemical reported tumors in rats receiving AN in a study sponsored by the Manufacturing Chemists Association (MCA). In May of that same year, a DuPont study reported above-average cancer among workers exposed to AN at a textile fibers plant (IRLG, 1978, p. 60). Because of the new evidence on the carcinogenicity of AN, OSHA issued an emergency temporary standard (ETS) of 2 ppm (PEL) on January 17, 1978 and finalized that limit in October of the same year.

EPA acted on AN in 1979 and 1980, proposing and promulgating water quality criteria for AN and listing AN as a hazardous solid waste. A more complete listing of regulatory milestones is briefly summarized in Table 4.

Table 4. Establishment of Standards and Regulations for Acrylonitrile

1942	First animal toxicity data published for AN.
1944	Several cases of AN poisoning in workers reported.
1947, 52, 59, 61, 65, 66, 70s	Numerous animal toxicity studies published on AN exposure.
1971	ACGIH recommended a 20 ppm TWA occupational exposure limit to AN.
1971	OSHA published first standard (20 ppm PEL) for AN.
June 1976	FDA issued interim regulation for indirect food additive uses of AN copolymers.
March 1977	FDA stayed regulations permitting use of AN in beverage bottles.
March 1977	Dow Chemical (under MCA sponsorship) released a study showing animal carcinogenicity as a result of AN exposure.
May 1977	DuPont study reported above average worker carcinogenic incidence in an acrylic fiber manufacturing plant.
June 1977	OSHA and NIOSH requested AN producers and end users to submit information on worker exposure to AN.

June 1977 - November 1979	Monsanto lawsuit, public hearing, and litigation on beverage bottle stay.
September 1977	NIOSH recommended in a Criteria Document sent to OSHA that workplace exposure to AN be limited to 4 ppm PEL.
1978	Inter-governmental Regulatory Liason Group (IRLG) established AN task force.
January 1978	OSHA issued an Emergency Temporary Standard reducing permissible AN exposure to 2 ppm PEL.
October 1978	OSHA issued permanent standard (2 ppm PEL).
October 1979	EPA proposed water quality criteria for AN.
December 1979	EPA proposed rule under section 8(d) of TSCA requiring industry to submit health and safety data relating to AN.
May 1980	EPA listed AN as a hazardous solid waste.
September 1980	CPSC requested public comment on its determination that exposure to AN from consumer products is insignificant.
November 1980	EPA promulgated water quality criteria for AN.
January 1981	EPA listed AN as a hazardous air pollutant.
July 1981	IRLG suspends AN task group based on the completion of planned agency actions and/or the lack of current high level of interest.

AN has been subject to two short pre-regulatory periods immediately preceeding the OSHA standards, the first being a single year (1971) marked by a recommended standard and the second, starting with the March, 1977 evidence of AN carcinogenicity and ending upon issuance of the second OSHA standard in October, 1978. The EPA actions beginning in October, 1979 through January, 1981 might also be thought of as a third pre-regulatory period, but is not useful for consideration in this analysis because it is too recent.

D. ANALYSIS OF REGULATORY IMPACT

Based on the preceeding summary of environmental concerns and regulatory events affecting AN, the focus of suspect hazard concerns is in the actual manufacturing of the compound and in its use as a raw material in the manufacture of acrylic fibers, plastics and elastomers. Once acrylonitrile is incorporated (polymerized) into an end-product form, there has been little or no evidence of hazard potential. Most regulatory scrutiny of AN has thus been focused on occupational exposure hazards of workers engaged in the manufacture of AN, and its consumption in acrylic fibers, plastics, and elastomers. It is also these user categories, accounting for 75% of total AN demand, when public information to assess suspect hazard designation impact is most complete. Therefore, in this section trends will be examined in the production of AN and its consumption in these three major use categories to assess whether designation as a suspect toxic hazard affected the production and uses of AN.

1. Acrylonitrile Production

As noted earlier in Supply Factors, AN production was revolutionized with the introduction of the catalytic Sohio process. Not only did AN production costs decrease via this process because of the use of less costly raw materials, but improved yields of AN have resulted from an ongoing emphasis on catalyst research. Originally, from 1960 to 1967, this process employed the Sohio catalyst (Catalyst A) of bismuth phosphomolybdate composition. From 1967 to 1972, the uranium-based catalyst (Catalyst 21) was utilized. In 1972, Sohio replaced Catalyst 21 with "Catalyst 41," a uranium-free fluid-bed catalyst based on bismuth phosphomolybdate, which reportedly increased AN yield theoretically by 35% over the AN yield using Catalyst 21 (EPA, 1978, p. 11).

AN production was also affected by the increase in crude oil prices from the oil supply disruptions of 1973 and 1979, resulting in increased costs for propylene and ammonia and consequently for the production cost of AN. The general economic recession of 1975 and ensuing general price inflation also

affected AN manufacture. Figures 1 and 2, respectively, present domestic AN production and price trends, with these relevant economic and technological events and two major regulatory events of the 1970s noted.

Apart from possible impacts of suspect hazard designation on AN, it appears that changes in AN production and price trends correlate closely with these general economic and technological events. Surges in AN price correlate with the two oil supply shortfalls (and concomitant oil price increases); increases in production correlate with the introduction of new catalysts; and declines in production correlate with the economic recession. The 14% AN production decline of 1975 is of the same magnitude as the decline in the Chemical and Allied Products production index (16%) for that year.

Expert opinion and analysis appear to differ as to the impact of suspect hazard designation or regulation on prices and production. In an economic impact assessment prepared for OSHA (1978 pp. 1-8, 6-14), the costs of the 1978 2 ppm PEL standard to AN producers were estimated to be 1.64% of the value of annual AN and AN-based product sales, and it was further estimated that 94% of these costs would be passed on in the form of higher prices, amounting to a minor 0.69% price increase of AN.

This study also stated that (OSHA, 1978, p. 6-12):

AN production itself is in one of the strongest positions . . . in terms of ability to pass costs along in the form of higher prices to AN purchasers. Demand for AN is entirely a derived demand, depending on the products using AN. AN accounts for less than half of the cost of these latter products, usually very much less. AN is also indispensable in the production of all AN-based products, and the amount used is governed more by process input requirements than any other factor. All of these considerations suggest that the demand for AN itself is highly inelastic. Moreover, considerable expansion of capacity is planned, which reflects solid growth prospects. Thus it is estimated that all costs are passed on in the form of prices.

It has been reported (Kirk-Othmer, Vol. 1, p. 422; EPA 1978, p. 23) that

Figure 1. Domestic Production of Acrylonitrile (mill. lbs.)

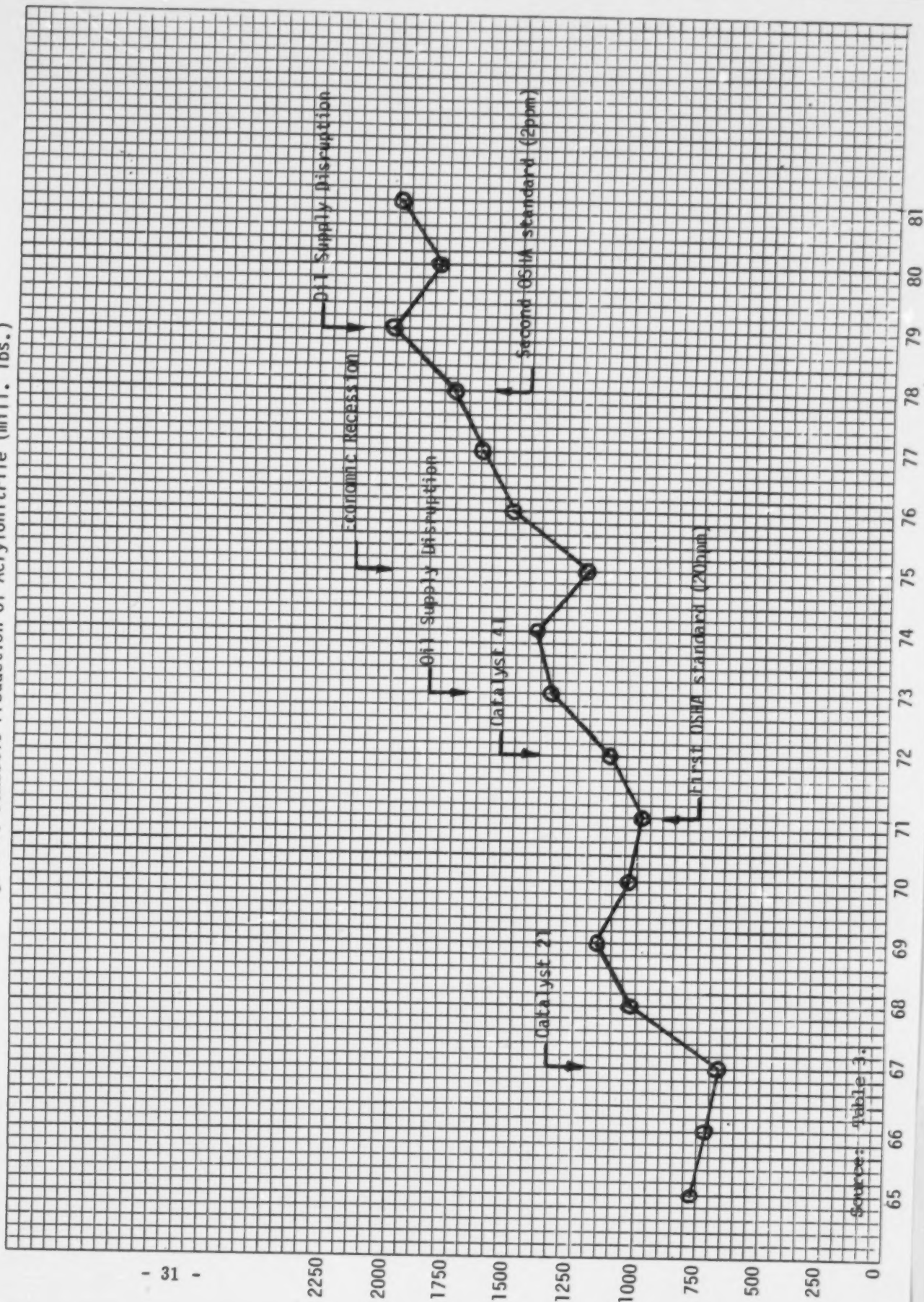
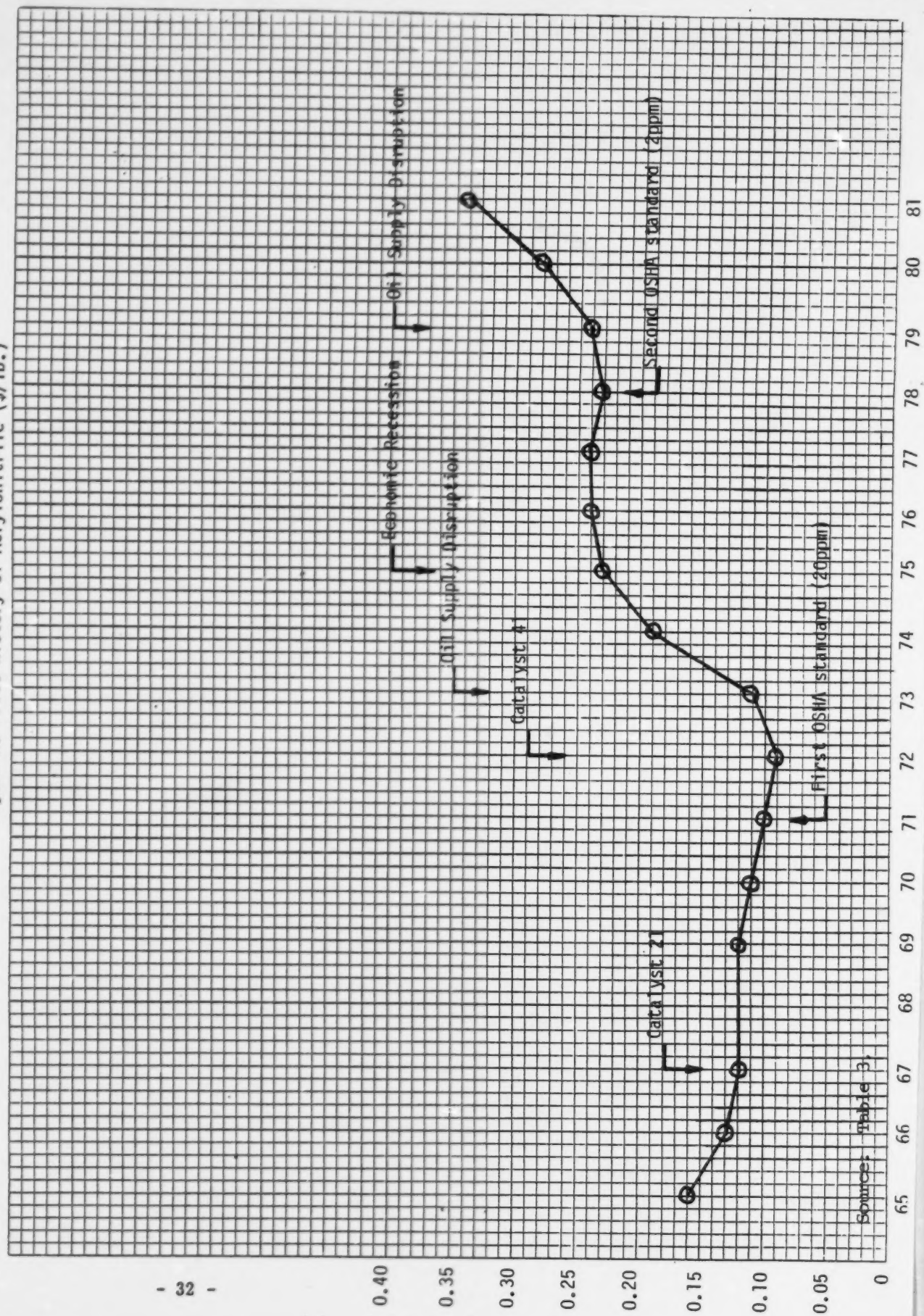


Figure 2. Price History of Acrylonitrile (\$/lb.)



Source: Table 3.

enforcement of ever increasing environmental standards has had an adverse effect on the production cost of AN, and that capital costs for the same size plants, have risen threefold over 1960 levels, particularly because of the added cost of required environmental control equipment.

Inspection of time series trends in Figures 1 and 2 do not allow one to judge the impact of economic/technological events apart from regulatory and suspect hazard events. Both major OSHA standards and many suspect hazard events beforehand occurred generally at times of constant or slightly declining prices and increasing production, and production/price trends are consistent with explanations based on economic/technological factors rather than regulatory or suspect hazard designation. The precise impact of suspect hazard designation in softening or strengthening these economic/technology-induced changes thus cannot be estimated.

2. Acrylic Fibers

In the 1950s, AN found its greatest use in synthetic fibers, and to this day synthetic fibers claim the largest portion of AN consumption. Acrylic fibers are the most wool-like of the synthetic fibers, a property that, together with moderate cost, has caused the fibers to find wide applications. Other synthetic (e.g., polyester, nylon) or natural (cotton) fibers could be used as substitutes for acrylics in replacing wool in its markets.

As shown in Table 2, acrylic fiber production has steadily increased. A better indicator of its performance, however, is to compare it with substitute fiber production. These data are provided in Table 5. Acrylic fiber's share of the fiber production market has been increasing compared to wool and cotton but decreasing compared to polyester and nylon. This can be explained by a general trend from use of natural fibers to synthetic fibers and also by differences in characteristics of synthetic fibers. Acrylic fibers, as natural fiber substitutes, seem to be limited to apparel and carpeting applications whereas polyester and nylon fibers are natural fiber substitutes for many other applications in addition to

Table 5. Relative Production and Price of Acrylic Fiber to Substitutes

Year	Acrylic Polyester		Acrylic Nylon		Acrylic Cellulosic (Cotton)		Acrylic Wool	
	Production	Price	Production	Price	Production	Price	Production	Price
1965	NA	0.19	NA	NA	0.24	0.33	0.68	0.25
1967	0.70	0.19	0.37	0.12	0.29	0.25	0.89	0.21
1970	0.48	0.27	0.36	0.13	0.36	0.23	1.45	0.26
1971*	0.48	0.27	0.34	0.14	0.39	0.21	2.09	0.27
1972	0.27	0.26	0.32	0.14	0.45	0.18	2.21	0.18
1973	0.26	0.30	0.34	0.16	0.55	0.21	3.48	0.12
1974	0.22	0.41	0.30	0.26	0.53	0.24	4.24	0.17
1975	0.18	0.48	0.28	0.29	0.70	0.24	3.36	0.20
1976	0.19	0.45	0.29	0.31	0.74	0.26	3.57	0.28
1977	0.19	0.43	0.30	0.28	0.80	0.24	4.03	0.35
1978*	0.19	0.43	0.28	0.27	0.80	0.22	3.88	0.29
1979	0.18	0.40	0.28	0.26	0.82	0.20	4.40	0.25
1980	0.20	0.38	0.33	0.26	0.97	0.20	4.58	0.27
1981	0.16	0.40	0.30	NA	0.90	NA	NA	NA

* OSHA standards

Source: Predicasts Basebook, pp. 120, 339, 342, 343.

apparel and carpeting. Relative price changes seem to correlate well with observed production trends except for comparison with wool, which exhibits erratic price/production behavior.

It is possible that compliance with the 1971 and 1978 OSHA standards added to acrylic fiber prices from passed-on capital costs of engineering controls in plants producing AN and fibers. However, for each of the four substitutes examined, relative acrylic prices declined with respect to all substitutes except nylon in 1972 and 1979, the years immediately following the regulations, suggesting that the costs of compliance may have been relatively insignificant in terms of pass-through of costs into fiber prices.

The one pre-regulatory event specific to this principal use category was the May 1977 DuPont study of worker cancer in an acrylic fiber plant. It might be hypothesized that an impact could have resulted from this event, but no significant adverse effects were observed in terms of either absolute and relative acrylic fiber production.

3. ABS/SAN Resins

As noted in Table 2, production of ABS/SAN resins peaked in 1979 and started a decline back to the 1976 level. Comparison of relative production and price trends with substitute resins does not provide much insight or explanation for changes in ABS/SAN use. For example, in Table 6, the relative production of ABS/SAN resins compared to all styrene resins (an aggregate resin indicator) remains fairly constant in spite of a decreasing relative price. Comparison with polystyrene shows an erratic relation between production and price.

Table 6. Relative Production and Price of ABS/SAN Resins and Substitutes

Year	<u>ABS/SAN Styrene</u>		<u>ABS/SAN Polystyrene</u>	
	Production	Price	Production	Price
1971	0.19	1.53		
1972	0.16	1.61	NA	1.78
1973	0.17	1.50	0.23	1.84
1974	0.17	1.24	0.23	1.69
1975	0.16	1.27	0.22	1.33
1976	0.21	1.31	0.20	1.35
1977	0.20	1.37	0.27	1.47
1978	0.19	1.40	0.28	1.82
1979	0.21	1.18	0.26	1.79
1980	0.19	1.16	0.30	1.59
1981	0.16	1.30	0.26	1.31
			0.22	1.59

Source: Predicasts Basebook, pp. 328-330.

Production and price trends for ABS/SAN resins do not seem to exhibit impacts from regulatory designation. Some companies have claimed there is no direct substitute for AN-based plastics, because AN imparts very specific qualities to these products, particularly chemical resistance. Behavior of this principal use category from Table 6 appears to confirm the suggestion that the demand for AN itself is highly inelastic.

4. Nitrile Rubber

Nitrile rubber is formed by copolymerizing AN and butadiene, with higher proportions of AN resulting in higher oil and gas resistance of the rubber. It is generally reported that a wide variety of substitutes exist for nitrile rubber. However, as Table 7 shows, there appear to be no real substitute elastomers for applications requiring hydrocarbon resistance, as evidenced by the poor ratings of substitute elastomers (except chloroprene), compared with the excellent and good ratings given nitrile rubber for this property.

Production of nitrile rubber has fluctuated (as Table 2 illustrates) from a high of 197.2 million pounds to a recession low of 121.5 million pounds in 1975. After rebounding in 1976, production has generally declined.

Table 7. Relative Properties of Elastomers^a

	Natural rubber	Synthetic polyisoprene	Styrene-butadiene rubber	Polybutadiene	Ethylene-propylene rubber	Butyl rubber	Chloroprene rubber	Nitrile rubber
<i>Physical properties</i>								
tensile	E	E	E	F	F	F	E	G
elongation	E	E	G	E	E	E	E	G
resilience	E	E	G	E	E	E	E	G
compression set	G	G	G	G	G	F	G	G
rebound cold	E	E	G	F	G	P	G	G
rebound hot	E	E	G	F	G	P	G	G
adhesion to metals	E	F	F	G	G	G	F	F
adhesion to fabrics	E	E	G	G	F	G	F	G
<i>Resistance properties</i>								
abrasion	E	E	E	F	G	F	E	G
tear	G	G	G	F	G	F	G	G
crack	F	F	F	F	F	E	F	F
oxidation	F	F	F	F	G	E	G	G
<i>Chemical resistance properties</i>								
with the hydrocarbons	P	P	P	P	P	P	G	E
acids, inorganic	F	F	F	F	F	P	F	G
acids, concentrated	G	G	G	G	F	E	E	G
alkalis	E	F	G	G	G	E	G	G
water absorption	G	G	G	G	G	G	E	G

Code: E, excellent; G, good; F, fair; P, poor. Rating applies only to the individual property, not which it is indicated and may be available only in compounds specifically designed for the particular service.

Source: Kirk-Othmer, v.8, p. 483.

To examine whether source of the reduced production and use of nitrile rubber could potentially result from the lower price of reported substitutes, Table 8 was prepared. It provides relative price and production for nitrile rubber, three reported substitutes, and total synthetic rubber. Relative production of nitrile rubber declined in all cases. However, its relative price also declined, indicating that relative price changes offer no logical economic explanation for the observed production changes.

As with acrylic fibers, it is possible that mandatory engineering controls to limit worker exposure to AN in the manufacture of nitrile rubber in compliance with the 1971 and 1978 standards resulted in pass-throughs of such costs into higher prices. However, relative price declined after both OSHA standards, suggesting that such impact was not visible. It has been reported that the nitrile rubber production decline in the later period was partly attributed to the rubber strike of 1976 (EPA 1978, p. 32). However, it is not clear why the economic impact of the strike did not proportionately affect all categories of rubber production.

The relative production decline after both OSHA standards (in 1971 and 1978) correlates with regulatory scrutiny from designation of AN as a suspect hazard and the implementation of AN regulations. However, because it was not evident that substitutes existed for nitrile rubber in oil-resistant applications, it is not clear that regulatory actions were the cause of the observed production declines. A general decline in economic activity in those industries using nitrile rubber products might offer adequate explanation for these trends, but this factor could not be adequately investigated. Thus an estimate of suspect hazard and regulatory impact is not possible for nitrile rubber based on the data presented.

E. SUMMARY

In summary, AN has been subject to a quite extensive regulatory history beginning with toxicity studies in the 1940s, two short pre-regulatory periods consisting of two recommended standards, an emergency temporary standard,

Table 8. Relative Production and Price of Nitrile Rubber and Substitutes

Year	Nitrile Butyl		Nitrile Polybutadiene		Nitrile Natural Rubber		Nitrile All Synthetic Rubbers	
	Production	Price	Production	Price	Production	Price	Production	Price
1965	0.57	NA	0.38	2.14	0.13	1.81	0.10	1.34
1967	0.54	NA	0.31	2.42	0.14	2.30	0.09	1.39
1970	0.57	NA	0.24	2.76	0.13	2.14	0.08	1.57
1971*	0.62	0.88	0.26	2.71	0.13	2.56	0.07	1.48
1972	0.57	0.82	0.25	2.20	0.13	2.44	0.07	1.38
1973	0.52	0.85	0.25	2.32	0.14	1.26	0.08	1.29
1974	0.56	0.78	0.28	1.85	0.14	1.25	0.08	1.16
1975	0.69	0.74	0.19	1.97	0.09	1.90	0.11	1.14
1976	0.62	0.68	0.22	2.03	0.12	1.56	0.08	1.09
1977	0.33	0.68	0.20	1.91	0.10	1.55	0.07	1.12
1978*	0.32	0.61	0.19	1.89	0.11	1.36	0.06	0.97
1979	0.27	0.58	0.19	1.74	0.10	1.12	0.06	0.95
1980	0.18	0.80	0.21	1.44	0.11	1.07	NA	NA
1981	0.18	NA	0.19	1.19	0.10	1.21	0.06	0.71

* OSHA standards

Source: Predicasts Basebook, pp. 338, 339.

evidence of AN carcinogenicity, OSHA/NIOSH AN information requests, and actual regulatory events (1971 and 1978) marking the implementation of AN worker exposure standards.

To assess the impact of this regulatory scrutiny, trends in the production and use of AN were examined together with supply factors for AN production and three principal use categories, fibers, resins, and elastomers.

Economic factors such as the 1975 recession and oil supply disruptions, and improvements in the AN manufacturing process generally correlated closely with changes in producer/user behavior, and could not be separated from impacts of either pre-regulatory designation or implementation of actual standards.

SECTION II.2

REGULATORY IMPACT ANALYSIS FOR ARSENIC

The purpose of this summary is to report on the potential market impact of designating arsenic as a suspect toxic hazard. An estimate of such impact depends upon careful examination of consumption and use characteristics together with supply factors and regulatory history.

A. SUPPLY FACTORS

The potential supply of arsenic depends on the processing of copper and lead, and to a lesser extent, zinc, gold, and silver, since arsenic is a minor constituent and by-product of these ores and must be removed during recovery of the base metal.

Total U.S. supply is the result of both domestic refining and imports. In addition, until recently, it was a result as well of the drawing down of the total U.S. stock of the metal. Exhibit I shows the distribution over time of arsenic production between domestic refinery production, imports, and stock drawdowns. As can be seen from the Exhibit, about 60% of the total U.S. supply consists of imports. About 80% of domestically refined arsenic is from ores and concentrates which are mined abroad, as Exhibit II indicates. As indicated in Exhibits I and II, total U.S. supply has decreased since reaching a high point in the early 70s, with an overall drop in both domestic refined production and imports. Arsenic is produced in about 15 countries on five continents. The largest countries over the past 10 years in order of importance have been Sweden, France, Mexico, Philippines, USSR, Peru, and South and West Africa. Asarco of Tacoma, Washington, a copper producer, is the sole domestic producer of arsenic compounds and arsenic metals. They are produced as by-products. Arsenical residues from other copper smelters and lead plants supplement arsenic recovered from copper concentrates at Tacoma.

EXHIBIT I
ARSENIC PRODUCTION DISTRIBUTION
(short tons of contained arsenic)

<u>Year</u>	<u>Total U.S. Supply</u>	<u>Domestic Refining Production</u>	<u>Imports (compounds & metals)</u>	<u>Industry Stocks</u>
1969	27,000	10,300	14,400	2,300
1970	32,200	10,900	14,900	6,400
1971	33,240	7,500	13,840	11,900
1972	35,070	10,300	11,170	13,600
1973	35,790	10,200	9,490	16,100
1974	30,300	7,400	11,300	11,600
1975	20,200	8,100	9,600	2,500
1976	14,000	7,300	3,500	3,200
1977	13,530	5,330	4,900	3,300
1978	14,900	6,360	8,200	340
1979	16,260	6,350	9,770	140
1980	NA	NA	NA	60

Source: USBOM Mineral Facts and Problems, 1980, p. 50.

EXHIBIT II

DOMESTIC REFINERY INPUTS
(short tons of contained arsenic)

<u>Year</u>	<u>Domestic Mines</u>	<u>Imported Ores and Concentrates</u>
1969	2,500	7,800
1970	2,300	8,600
1971	2,100	5,400
1972	1,900	8,400
1973	2,100	8,100
1974	1,500	5,900
1975	1,600	6,500
1976	1,100	6,200
1977	930	4,400
1978	1,200	5,160
1979	860	5,490

Source: USBOM Mineral Facts and Problems, 1980, p. 50.

Several elements are important to understanding the downward domestic supply pattern.

- U.S. and world copper strikes causing disruptions which placed temporary pressures on U.S. supply (1971, 1973, 1974, 1980).
- Federal, and especially local, regulation beginning in 1974 with respect to sulfur dioxide emissions for Asarco. These regulations forced Asarco to cut back its smelter operations significantly, substantially reducing the availability of by-product arsenic.
- World environment regulations governing refining, smelting, and uses in major foreign countries, such as Sweden, which export to the U.S.
- Tightened work place exposure rules for arsenic production in the U.S., requiring investment in new technologies and production measures.
- World-wide recession in 1975, reducing demand for primary metals and thus the arsenic by-product.
- Decline in certain uses caused by both economic factors as well as regulation. For example, inorganic arsenicals were mainly used in pesticides for many years, but have been virtually discontinued. Likewise, glass production has declined from 10% to 5% of total arsenic use.

Though prices have risen for arsenic compounds, significant increases in domestic supply have not been forthcoming. There has been no new entry in several years though two new plants were scheduled to begin production by the end of 1982. (A regression fit of prices on domestic supply showed no significant positive correlation for the past several years.) Moreover, Asarco has operated significantly less than full capacity. Yet, conditions would appear to be suitable for price incentives to operate. For example, the price of imported arsenic in the form of the major compound form in which it is consumed—arsenic trioxide—has been significantly and persistently higher for several years than the domestic price, as Exhibit III shows. Moreover, many industry observers have spoken of a genuine supply shortage since the mid- to late 70s. Asarco cites local environmental regulations as almost the sole cause of its failure to increase supply

EXHIBIT III
TIME-PRICE RELATIONSHIPS FOR ARSENIC
(cents per pound)

<u>Year</u>	<u>Domestic Price of Arsenic Trioxide</u>	<u>Import Price</u>
1958	5.50	
1959	4.50	7.2
1960	4.50	5.9
1961	4.00	5.9
1962	4.00	5.3
1963	5.10	5.3
1964	5.25	6.7
1965	5.70	6.9
1966	5.53	7.5
1967	6.25	7.3
1968	6.13	8.2
1969	6.50	8.1
1970	6.50	8.6
1971	6.50	8.6
1972	6.50	8.6
1973	6.50	8.6
1974	13.00	8.6
1975	21.50	17.1
1976	20.50	28.3
1977	20.50	27.0
1978	30.00	27.0
1979	32.00	39.5
1980	35.00	42.1
		46.1

Source: USBOM Mineral Facts and Problems, 1980, p. 50.

(Lederer & Fensterheim, p. 4). As a condition of Asarco's continued operation, the Puget Sound Air Pollution Control Authority (PSAPCA) has required Arsarco to remove 90% of the sulfur dioxide generated in the environment by 1987, which has substantially reduced the availability of by-product arsenic from the refining process. Arsarco indicates that this would cost approximately \$100 million in new investment expenditures and simply could not be afforded. Hence, it is apparent that supply constraints potentially act as an important factor in determining patterns of arsenic consumption and use.

B. CONSUMPTION AND USE CHARACTERISTICS

Four major pesticide and desiccant producers and two major wood preservative producers consume 90% of all arsenic. The Environmental Protection Agency has registered 230 companies manufacturing product containing arsenic. Estimated distribution in 1981 was 45% in industrial chemicals (wood preservatives and mineral flotation reagents); 45% in agricultural chemicals (herbicides and plant desiccants); 5% in glass and ceramics; 3% in nonferrous alloys; and 2% in other uses (animal feed additives and pharmaceuticals). About 97% of arsenic consumed in end-product manufacture is in the trioxide form (As_2O_3), with the uncompound metal accounting for the remaining 3%.

This usage pattern has shifted dramatically in the past several years, as Exhibit IV makes clear. Agricultural uses have declined from 70% of the total arsenical consumption in 1979 to 45% in 1981, while wood preservative uses have risen from 18% to 45% of total use over the same period. The following sections examine each of these two major uses in greater detail.

1. Agricultural Chemicals

Arsenic compounds utilized in the agricultural industry are employed mostly in the production of cotton. This use accounted for about 70% of the total agricultural chemical demand for arsenic in 1979. Most arsenic for agricultural chemical use is for organic herbicides. However, agricultural chemicals contain-

EXHIBIT IV

USES OF ARSENIC

<u>Use</u>	<u>Short tons (2000 lbs) Demand 1979</u>	<u>% Total Use</u>		
		<u>(K-O) 1974</u>	<u>(USBOM) 1979</u>	<u>(USBOM) 1981</u>
Agriculture (Herbicides, Desiccant)	11,300	65	70	45
Industrial a) Wood preservative	3,300	18	20	45
b) Mineral flotating reagent for separation of copper sulfide and molybdenum sulfide ores				
Glassware/Ceramics	800	10	5	5
Nonferrous alloys (electronics, batteries)	500	3	3	3
Animal feed additive (poultry)/other	300	4	2	2
TOTALS	16,200	100	100	100

SOURCES: 1. USBOM Minerals Yearbook, 1981, p. 940.
2. USBOM Minerals Facts and Problems, 1980, p. 50.
3. Kirk-Othmer, vol. 3, p. 251.

ing arsenic also include plant desiccants and defoliants, insecticides, soil sterilizers, insect baits, and sheep dips. Specifically, the organic arsenic herbicides monosodium methanearsonate (MSMA), disodium methanearsonate (DSMA), and cacodylic acid (dimethylarsinic acid), which are produced from arsenic acid, are used extensively for the control of crabgrass in noncrop areas and for the control of Johnson grass in the cotton-producing areas of the South and Southwest United States. Cacodylic acid is a nonselective contact herbicide used for general weed control. Arsenic acid is used as a desiccant for stripper-harvested cotton in Oklahoma and Texas. The acid serves the dual purpose of rendering plant parts brittle for mechanical stripping and prevents green staining of the cotton bolls.

Exhibit V shows the demand pattern for arsenic's use as an agricultural chemical for 1969-1981. Since 1974 U.S. agricultural chemical demand for arsenic has exhibited a fluctuating but steady decline. This loss in absolute consumption has been accompanied by a gain in the market position of several non-arsenical substitutes — mainly trifluralin, fluometuron, and the phenyl ureas. Exhibit VI shows the consumption of arsenic for its main agricultural use in cotton production for selected arsenical organic herbicides and two major competing products for 1971 and 1976, the only two years for which data were available. The National Cotton Council of America has provided more recent data on the declining use of the arsenicals as the herbicide of choice in cotton production. The Council has estimated an approximate 10% annual reduction in use of arsenic trioxide between 1979-1981 based on number of acres planted. (National Cotton Council of America, 1980, 1981, 1982.)

EXHIBIT V

U.S. AGRICULTURAL CHEMICAL DEMAND FOR ARSENIC
1969 - 1981
(short tons of contained arsenic)

<u>YEAR</u>	<u>DEMAND</u>
1969	16,300
1970	16,100
1971	15,600
1972	15,100
1973	19,700
1974	22,800
1975	14,000
1976	7,500
1977	9,200
1978	10,300
1979	11,300
1980	NA
1981	NA

Source: USBOM, Mineral Facts and Problems, p. 50.

EXHIBIT VI

TOTAL CONSUMPTION OF ARSENICAL ORGANIC AND COMPETING HERBICIDES FOR COTTON USE, 1971 AND 1976 (Thousands of pounds)

	<u>1971</u>	<u>1976</u>
Arsenical Organics	7,569	3,280
Fluometuron	3,334	5,284
Trifluralin	4,544	6,980

Source: USDA, 1974, 1978.

2. Industrial Chemicals

The chief use for arsenic in industrial chemicals is in making the wood preservative copper-chromated arsenate (CCA), which, for the most part, has been the preferred substitute for fluor-chrome-arsenate-phenol (FCAP). Creosote and pentachlorophenol may also sometimes be used as substitutes for arsenical wood preservatives.

Consumption of wood preservatives in general and CCA in particular have shown strong growth during the 1970s. One report puts growth in demand for wood preservatives at 30% per year since the late 1970s, and has attributed the advantage being enjoyed by CCA to its lower cost and wider acceptability compared with pentachlorophenol and creosote. Timber treated with CCA is non-toxic to animals, safe to handle, does not stain fabrics or taint foodstuffs, has improved hardness, does not corrode metal fastenings, does not ignite early, accepts paint without the need for sealers and can have high electrical resistance. Exhibit VII shows the growth picture in somewhat more detail.

EXHIBIT VII

USA: CONSUMPTION OF WOOD PRESERVATIVES 1976 TO 1981

	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>
CCA (t)	7,755	11,237	11,322	15,315	18,000	19,000
FCAP (t)	111	NA	102	NA	100	100
Pentachloro- phenol (t)	17,661	NA	NA	NA	NA	NA
Creosote (mill gal)	95	NA	NA	NA	NA	NA

Source: Roskill Information Services, p. 25.

C. REGULATORY HISTORY

Arsenic has a history of extreme toxicity in its production and major uses. Its work place hazard potential has long been known. High levels of arsenic air pollution have been recorded in U.S. copper smelting plants as early as 1907. In addition, as an organic herbicide, arsenic may upset plant metabolism and interfere with normal growth. As a wood preservative, some patterns of arsenic compounds may result in toxic residues in food or feed from exposure to wood subjected to arsenical treatment.

Given its toxicity, arsenic has been the subject of extensive regulatory activity at both the production and use levels. Worker exposure to airborne concentrations of arsenic trioxide was first controlled by OSHA in the late 60s. In 1973, NIOSH revealed the results of studies showing the carcinogenic potential of arsenic, leading to a series of meetings in 1974 with industry, and to a standard proposed in 1975 that significantly reduced exposure limits over the earlier standard. This new standard was finalized in 1978, and set exposure limits at the refining stage as well as for arsenic residue from cotton ginning and herbicide manufacture. In 1978-9, the standard was vigorously litigated, with the courts granting a partial stay (1979) and two years later, ordering OSHA to make a risk assessment of the entire arsenic worker health problem. As of late 1983, this assessment was still ongoing.

In addition, an indirect but important regulation was put in place in 1974-5 as major refiners were subjected to stringent sulfur dioxide emission standards for their smelting operations by both EPA and, to an even greater extent, local authorities. The Asarco Tacoma smelter is liable to comply with emission standards set by the Puget Sound Air Pollution Control Agency (PSAPCA). To date, the PSAPCA has sought to limit sulphur dioxide emissions only, but this regulation substantially reduced the availability of by-product arsenic, a situation only partly alleviated by a partial variance granted by PSAPCA in 1976.

In 1980, EPA designated arsenic a hazardous air pollutant under Section 112 of the Clean Air Act, indicating that industry-by-industry, emission standards would be established for the metal refinery operations of which it is a by-product. More recently, EPA proposed an overall 17% reduction in arsenic emitted into the atmosphere by copper smelters, glass-manufacturing plants and other sources. (Wall Street Journal, 7/13/83).

Besides the OSHA workplace standard, arsenic's major use as a herbicide has also been subject to other regulatory control and interest. The discharge of arsenic compounds has been under effluent guidelines control for metallo-organic pesticides under the Federal Water Pollution Control Act since 1972, and under an interim primary drinking water limit as a result of the 1974 Safe Drinking Water Act (SDWA). The many herbicidal uses of arsenic have long been registered under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as required by law, since the late 1960s. In 1978, EPA indicated its intention to require additional health data for each of these uses. Over the past several years, several tolerances (allowable pesticide residues) have been granted to arsenicals for food crops, and several have been cancelled as well.

Arsenical use as a wood preservative has been the subject of more recent regulatory interest. In 1978, EPA asked wood preservative manufacturers, including manufacturers of arsenical compounds, for health data, and followed this request up in 1981 with a proposed list of regulatory options. A formal proposal for regulation was expected as of late 1983.

In addition, the IRL in 1981 expressed a renewed regulatory interest in arsenic by reactivating a Task Group. The incentive for inter-agency cooperation came in large part from a jurisdictional issue between EPA and FDA as to which agency has primary responsibility for regulating arsenicals that are both pesticides and animal drugs.

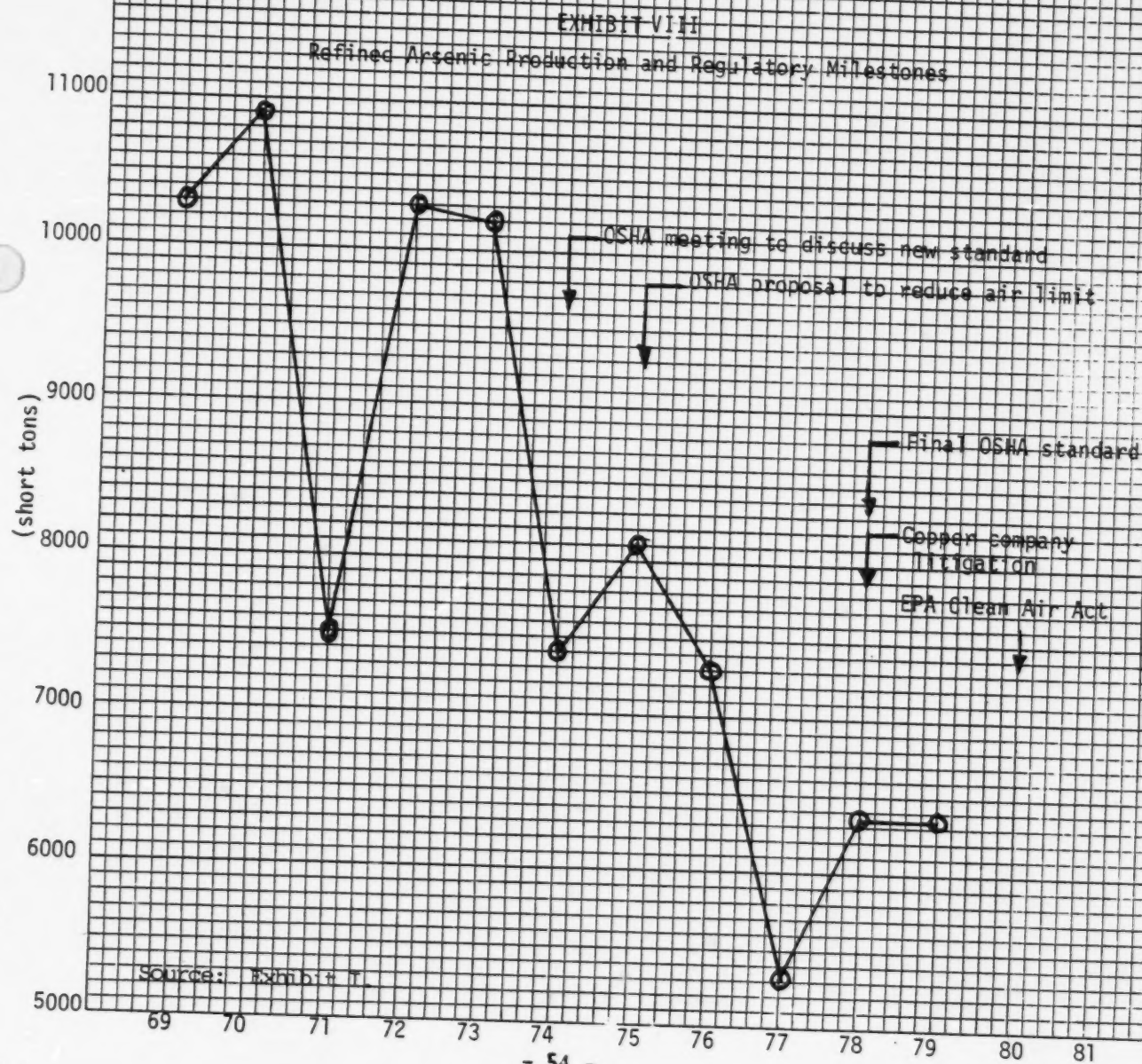
FDA has clear jurisdiction over the uses of arsenic in veterinary medicine for non-food animals, and as an approved food additive in swine and poultry feed. The agency's biggest concern is the use of arsenical herbicides for livestock forage, because poisoning of livestock can occur. Tolerances based on toxicity of arsenic are therefore enforced in: cotton hulls; kidneys and livers of horses and cattle; and meat, fat, and meat products of cattle and horses. Additional tolerances (including levels of arsenic in food products) have not been established.

D. ANALYSIS OF REGULATORY IMPACT

Three potential areas exist where the impact of suspect hazard designation could be potentially experienced: (1) smelting and refining; (2) herbicides; (3) wood preservatives. Each shall be discussed in order.

1. Smelting and Refining

Exhibit VIII presents supply trends and regulatory milestones for refined arsenic. Major potential suspect hazard designation for refined arsenic existed from approximately 1974 through 1979, the period immediately prior to OSHA's significantly tightened workplace exposure standards. As the Exhibit shows, this period of pre-regulatory designation corresponded closely with a significant decline in domestic production. (Likewise, production rose slightly when the decision to litigate occurred in 1978 and the litigation proved partly successful).



However, this decline can be explained almost entirely by two factors other than potential regulation. Both have been mentioned above: (1) reduction in output because of the need to comply with local sulfur dioxide emissions regulations; (2) supply factors including strikes, the 1974 recession, and increased imports from abroad because of country-specific supply constraints and environmental rules. According to Asarco, given the need to come into compliance with local sulfur dioxide emissions regulations, the anticipated need to comply with changes in work place exposure did not significantly affect domestic refining production.

Potential regulatory designation affecting refiners also occurred in 1980, when EPA announced its intention to regulate arsenic emissions on an industry-by-industry basis, and in July 1983, when EPA proposed reducing organic emissions by 17%. The time frame has been too short, however, to test the impact of these particular regulatory designations on refining behavior.

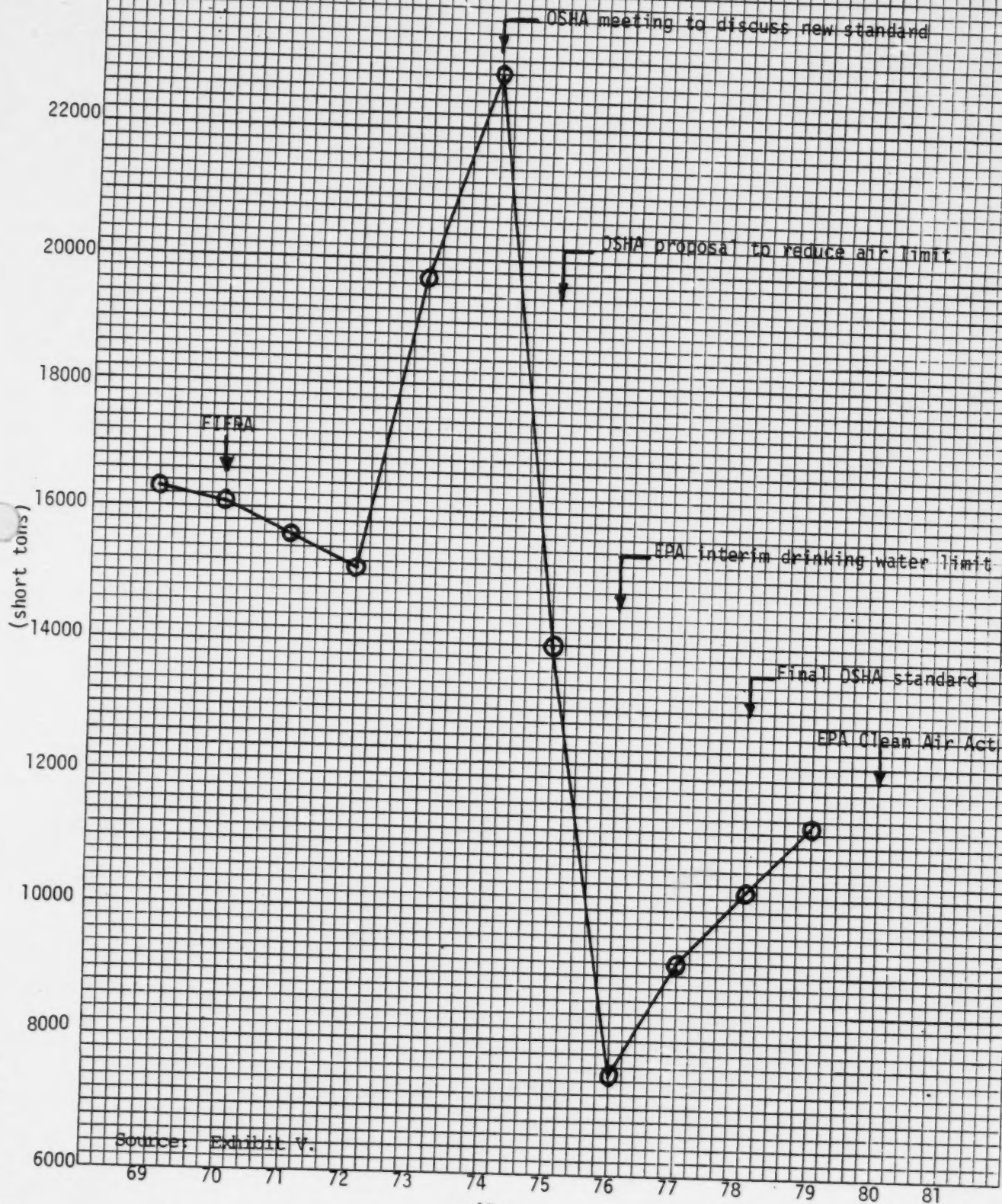
2. Herbicides

Exhibit IX presents supply trends for herbicide use together with regulatory milestones specific to herbicides. Again, the major potential suspect hazard designation for herbicides was the worker exposure rule discussed and then proposed in the period 1974-1977. Other regulatory designations were an interim drinking water rule in 1976 which has never been finalized and an EPA announcement in 1978 of its intention to seek additional health data under its pesticide regulations.*

Significant decline in agricultural chemical use began one year (1975) after suspect hazard designation, and intensified in the year of the drinking water

* Specifically, EPA sought such data under the Rebuttable Presumption Against Registration (RPAR) provision of FIFRA, which places the burden on industry to provide support for continued registration of particular pesticides for specific uses.

EXHIBIT IX Arsenical Herbicide Supply and Regulatory Milestones



interim announcement. Thus, the period of suspect designation coincided in a significant way with the decline. However, it was necessary to test whether other explanatory factors were also at work in explaining the decline in use. These include: (1) level of general economic activity; (2) price of substitutes; (3) level of activity in the general category of organic herbicides of which the arsenicals are a part; and (4) compliance with actual regulation. Each shall be discussed in order.

a. Level of General Economic Activity

To test whether trends in arsenical herbicide use are explained by trends in general economic activity, a comparison was made of arsenical herbicide use with trends in cotton production, the most specific general user category for which data were available. Exhibit X shows the ratio of use of arsenical herbicides in agricultural chemicals to cotton production for each year 1969-79. As the Exhibit indicates, beginning in 1976, there was a significant drop in the use of arsenicals in cotton production, from a ratio of 1.6 to 0.71. This latter ratio was maintained at approximately the same level in subsequent years. The similarity of the ratio for 1975 with ratios of earlier years, shows that the recessionary year of decline in cotton production approximately matched the decline in arsenic use. Thus, for 1976 and thereafter, the drop in the major category of use of arsenic in cotton production was not correlated with the overall level of such production. This indicates that one must look elsewhere than to the decline in cotton production to explain the decline in herbicidal use after 1975.

b. Relative Price Differences

To test whether declines in herbicidal arsenic use were correlated with relative price differences, the relative price of arsenic trioxide and a price index for the general category of organic herbicides were compared with relative production. Comparisons are expressed in Exhibit XI. As Exhibit XI shows, although arsenic rose in price in 1974 compared with earlier years (column 1) relative to other organics, it kept its relatively higher price after 1974

EXHIBIT X
COMPARISON OF AGRICULTURAL CHEMICAL USE AND
COTTON PRODUCTION
1969-1981

<u>Year</u>	<u>Agric. Chem. Demand (short tons)</u>	<u>Cotton Production (mill. of bales)</u>	<u>Ratio of Ag. Chem. Demand to Cotton Production</u>
1969	16,300	NA	NA
1970	16,100	10.19	1.60
1971	15,600	10.48	1.60
1972	15,100	13.70	1.30
1973	19,700	12.97	1.52
1974	22,800	11.54	1.98
1975	14,000	8.30	1.68
1976	7,500	10.58	0.71
1977	9,200	14.39	0.64
1978	10,300	10.86	0.94
1979	11,300	14.63	0.77
1980	12,131	11.12	1.09
1981	10,845	15.73	0.69

Source: USBOM, Mineral Facts and Problems, p. 50, and Predicasts Basebook, p. 112.

EXHIBIT XI

COMPARISON OF RELATIVE PRICE OF ARSENIC TRIOXIDE AND OTHER ORGANIC HERBICIDES WITH RELATIVE PRODUCTION FOR AGRICULTURAL CHEMICAL USE 1970-81

	(1)	(2)	(3)	(4)	(5)	(6)
	As ₂ O ₃ Price	Org. Herb. Price (index)	As ₂ O ₃ Ag. Chem. Prod. (short tons)	Org. Chem. Herb. Prod. (mill. lb.)	Rel. Price As ₂ O ₃ / Org. Herb.	Rel. Prod. As ₂ O ₃ / Org. Herb.
1970	14.3	1.68	16.1	380.6	8.5	4.2
1971	13.6	1.75	15.6	457.9	7.8	3.4
1972	13.1	1.81	15.1	451.3	7.2	3.3
1973	12.4	1.80	19.7	495.9	6.9	4.0
1974	22.4	2.00	22.8	604.2	11.2	3.8
1975	33.8	2.26	14.0	788.0	15.0	1.8
1976	30.7	2.58	7.5	656.1	11.9	1.1
1977	29.0	2.76	9.2	674.2	10.5	1.4
1978	39.5	2.76	10.3	663.6	14.3	1.6
1979	38.7	3.08	11.3	657.1	12.6	1.7
1980	42.3	3.34	12.1	805.7	12.7	1.5
1981	NA	4.02	10.8	839.1	NA	1.3

*Constant 1978 cents per pound.

Source: USBOM Mineral Facts and Problems, p. 50, Predicasts Basebook, p. 393.

(column 5). Its relative price movements by year do not appear to be significantly correlated with changes in use, although in a longer-run, secular sense, relative price might be more important as an explanatory factor.

c. Decline in General Category of Organic Herbicide Activity

To test whether the decline in herbicidal use was associated with a more general decline in organic herbicides, comparison of the relative production of arsenicals for herbicidal use and total organics was made. As Exhibit XI indicates, beginning in 1975, there was a significant decline in the production of herbicidal arsenic (column 3). Within the general category of organic herbicides, the organics were rising for the entire period (column 4). As column 6 makes clear, arsenic suffered a significant relative decline within the general organic category of organic herbicides beginning in 1975. Thus, the declining herbicidal arsenic trend cannot be explained by movements in general organic herbicide activity.

d. Impact of Actual Regulation

Unlike the situation for smelting and refining, our preliminary analysis indicates that implementation of an existing regulation did not appear to be a factor affecting herbicidal use during this period. The key regulations affecting herbicidal use pesticide regulations under FIFRA, had been implemented by the early 70s and their effect on production, if any, is most likely to have been felt at that time.

e. Summary

In summary, except for one year, 1975, regulatory designation appears significant in explaining patterns of herbicidal use decline. It is thus hypothesized that the combination of interim proposed safe drinking water regulations and proposed work place exposure regulation can be regarded as significant factors associated with herbicidal arsenic output decline for all years except 1975.

It must be emphasized that this conclusion is preliminary. Relative price, in a secular sense, might also account for the secular downward arsenic herbicide production trend. More definitive conclusions require analysis at the micro-level of the relation between arsenic compounds and substitutes, and more detailed data on the behavioral responses of industry to the regulatory and economic situation. Also, as noted above, total arsenic supply has been declining over the years examined, and this factor might override all other factors, regulatory and economic, in determining arsenical herbicide production and consumption.

3. Wood Preservatives

The key designation of regulatory intention for arsenic and competing compounds in wood preservatives came in 1978, with the EPA request for health information for all chemicals used in wood preservatives, and in 1981 with a proposed set of regulatory options affecting both arsenic and competing compounds in wood preservative use. As the previous discussion indicated, the request for health information did not affect the growth of the wood preservative industry or the growth of arsenic's role in that industry. In fact, growth of wood preservatives began to be significant in the same year as the initial regulatory announcement, while growth in arsenic's role in wood preservatives had begun two years earlier. A decline in the rate of growth occurred for 1981; however, industry spokesmen agree that this decline was the result of economic recession affecting the housing industry rather than to the regulatory designation for wood preservatives.

It would appear that as of the end of 1983, industry did not feel threatened by the proposed regulation affecting wood preservative use, for two reasons: (1) indications that EPA would adopt a voluntary standard that had been worked out largely with industry cooperation; (2) the proposed regulation would appear to affect all wood preservative competitors rather than simply arsenical producers or importers, and would not be expected to jeopardize the relative superiority of arsenic compounds.

E. SUMMARY

In summary, arsenic presents different pictures for the production and two use aspects studied.

- In smelting and refining, significant impact on production was observed, but was the result of compliance requirements with regulation rather than regulatory proposals or designation.
- In herbicidal use, significant impact was observed and appeared to be closely associated (except in one year, 1975) with regulatory designation since other factors were not revealed as significant.
- In wood preservative use, regulatory designation appeared to have no impact; indeed, any impact would appear to be in the opposite direction.

However, in estimating the potential market impact of designating arsenic as a suspect hazard, it is important to realize that the total domestic supply of arsenic (including imports) has been declining since 1973. Therefore, any observed correlation between regulatory events and arsenic consumption/production patterns may be due to supply constraints rather than regulatory impacts.

SECTION II.3

REGULATORY IMPACT ANALYSIS FOR BENZIDINE-BASED DYES

The purpose of this summary is to report on the potential market impact of designating benzidine-based dyes as suspect toxic hazards. An estimate of such impact depends upon careful examination of consumption and use characteristics together with supply factors and regulatory history. First, however, some general background information on the dye industry is required.

A. BACKGROUND

Benzidine-based dyes are a segment of the synthetic organic chemical dye market. This market has been characterized by below-normal growth relative to other chemical segments, for several reasons. First, demand from major users, the textile and carpet industry, has been relatively flat over several years. This fact led to significant over-capacity in the 1970s because expectations of growth were not realized. For the 10-year period 1971-1980, capacity exceeded domestic consumption by between 25% and 30%.

Second, imports grew significantly relative to domestic production — from 10% of total domestic production in 1965 (poundage basis) to 22% in 1980 (Source: Predicasts). There were several reasons for this:

- Many U.S. plants were antiquated relative to those of the major West European producers, who have spent substantially more than their U.S. counterparts on R & D and new investment, particularly in the energy conservation area. In addition, major foreign producers have integrated their dye operations with other organic operations to a much greater extent than their U.S. counterparts, and have a long tradition of competitive advantage in the dye industry.
- Importers have been more oriented to foreign markets and more aggressive in direct marketing efforts.
- Environmental regulations have been relatively more burdensome until recently in the U.S. than abroad, particularly the water pollution regulations of the 1960s which were not dupli-

cated in Western European producer countries until much later.

- The regulatory atmosphere has been more permissive for joint dye ventures abroad than in the U.S.
- Reduced tariffs under the General Agreement on Tariffs and Trade (GATT) narrowed the price disadvantage of imports in the mid-1970s.

Third, a major antitrust price-fixing prosecution and settlement in 1973 with the U.S. Justice Department had a greater impact on the domestic industry more than it did on foreign producers. As a result of the settlement, domestic producers dispersed their dye executives to other non-dye operations, thus weakening the trained executive talent pool. This factor was particularly important for Dupont, a large manufacturer who had just put a new large scale dye plant into operation. Foreign producers merely transferred their dye executives to other countries as a result of the settlement, maintaining them in dye operations, and thus not losing the advantage of their training and technical expertise.

The result of these factors has been a big shake-up of the U.S. dye industry. Since 1974 seven major American chemical companies have left the field, mainly to foreign firms acquiring their assets. The top five manufacturers are Western European — two are Swiss-owned (Sandoz and Ciba-Geigy) and three are West German (BASF-Wyandotte, American Hoechst, and Mobay). Major American producers include Crompton and Knowles, American Color, and Atlantic Chemical. Also in the market are Eastman Chemical, American Cyanamid, and Martin Marietta.

B. CONSUMPTION AND USE CHARACTERISTICS

Dyes in general are mainly used in textile applications, i.e. fibers and fabrics, both synthetic and natural, but also with paper, organic pigments, and other applications. To a great extent, the market is limited by the growth potential of these basic user industries, and the market for specific dyes is largely

dependent upon fashion and design preferences, which are somewhat unstable over time. Though some industry experts disagree, most indicate that dye costs for major uses are a relatively small percent of total product cost.

Benzidine-based dyes are used extensively to color textiles, leather, and paper. Ease of application and lower prices, estimated by several sources at a level approximately 25% lower than substitutes, have been a major asset to the general availability and widespread usage of the benzidine-based dyes. Of the total use, 40% is used to color paper, 25% to color textiles, 15% for leather, and 20% for diverse applications in the petroleum, rubber, plastics, wood, soap, fur, and hair dye industries. Exhibit I lists the major benzidine-based dyes and their uses.

Substitutes for benzidine-based dyes are generally numerous. Exhibit II, for example, shows the many substitutes for just one color category, the direct blues. However, some substitutes are not so readily available. A substitute for direct blue in leather dyeing has been difficult to obtain, for example. Substitutes, however, are generally higher in price and impossible to duplicate precisely, especially when combined with qualities such as fastness. Leading substitutes are chemicals of a similar chemical structure — the so-called benzidine congener-type dyes — but these have fallen under a regulatory cloud, and other substitutes of non-benzidine base are increasingly in demand. Five manufacturers now sell non-benzidine-based substitutes for the largest selling dye, Direct Black 38.

One of the specific uses of benzidine dyes has been singled out for special regulatory attention, i.e. use in consumer products. Dyes sold to consumers for crafts or home use — often called all purpose dyes — are usually packaged in small containers, varying in size between 1 3/4 oz. and 8 oz. in content. They are marketed in both liquid and powder form and they are available in supermarkets, hardware stores, and variety stores. The all-purpose dyes contain direct, acid and basic dyes, and their major use is in fabric applications. Among their other uses are candle making and leather crafts. The direct dyes are the most often used in fabric-dyeing crafts because of their ease of application and natural affinity for cotton, linen, and other fibers, as well as for leather.

HIBIT I

USES OF DYES CURRENTLY AVAILABLE IN THE UNITED STATES

Textile Dyeing and Staining		Acid Red 85	Direct Black 4	Direct Black 38	Direct Blue 2	Direct Blue 6	Direct Brown 2	Direct Brown 6	Direct Brown 31	Direct Brown 74	Direct Brown 95	Direct Brown 154	Direct Green 1	Direct Green 6	Direct Orange 8	Direct Red 1	Direct Red 28
Textile	Wool	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x
	Silk	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Man-made Fibers	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Textile Printing																	
Textile	Wool	x	x	x													
	Silk	x	x	x													
	Man-made Fibers	x	x	x													
Cotton																	
Leather Coloring		x	x		x	x	x	x	x	x	x	x	x	x		x	
Paper					x	x	x	x	x		x	x	x	x	x	x	x
Aqueous Inks				x		x							x	x			
Pigments							x		x		x					x	
Biological Indicators						x											x
Plastics		x	x														

Source: EPA, 1979, p. 6-47.

EXHIBIT II COMPARISON OF SHADE DIFFERENCES IN BENZIDINE-TYPE AND NON-BENZIDINE-TYPE DYES
IN THE BLUE RANGE, DIRECT DYE CHEMICAL CLASS

C.I. Blue (Correlated to Munsell Color Renotations)	Known Blue Direct Dyes based on Benzidine, o-Tolidine, and o-Dianisidine		Known Blue Direct Dyes based on Non-benzidine-type Derivatives	
	#	Color Index Name No.	#	Color Index Name No.
dull reddish blue	5	3,43,48,58,152	0	
reddish blue	7	19,27,31,42,49,65,151	8	29,55,116,121,135,140,194,201
bright reddish blue	1	177	2	107,203
dull blue	8	2,11,38,45,64,93,158,166	11	46,71,72,74,75,123,124,148,157,159,162
blue	23	4,6,8,9,10,12,14,15,21,22,23,25,35,50,78,84,98,136,168,183	30	34,54,67,70,81,82,97,100,110,120,120.1,122,128,130,138,145,180,184,185,195,200,221,222,232,233,234,236,237,256,261
bright blue	2	37,95	4	104,106,108,190
dull greenish blue	3	30,36,39	3	28,111,249
greenish blue	4	53,76,215,218	8	83,96,109,127,149,176,238,262
bright grnsh. blue	2	1,231	6	41,86,87,199,189,202
reddish navy	3	26,60,63	8	33,69,126,147,164,186,196,257
navy	3	51,131,150	5	167,172,175,246,250
greenish navy	1	16	1	132
TOTAL	62		86	

Source: CPSC, 1983.

It has been estimated by the U.S. Consumer Product Safety Commission (CPSC) that as of 1978-9 the consumer dye market accounted for approximately 5% of all dye sales, and that the proportion of benzidine dyes in that market was about 5% in turn of total consumer dye sales (CPSC, 1983, p. 3). This translated into approximately 30,000 lbs. in the years 1978-9.

C. SUPPLY FACTORS

Dyes in general are characterized by high manufacturing costs, arising out of the need for sophisticated technology, a high inventory investment per dollar of sales, specialized technical service for customers, a small-batch method of production and long production time cycles. There are six major product classifications for dyes: disperse and reactive, both used in poly/cotton and poly/wool fabrics; vat; azoic; acid, used in nylon carpet fibers; direct; and basic, used mainly for acrylics.

Benzidine-based dyes are among the cheapest dyes that have been available. They are mostly of the direct variety (although some acid, azoic, and disperse dyes are also benzidine-based), and as indicated above, are used mainly for textile, paper, and leather goods. In 1975, benzidine-based dyes accounted for approximately 35% of all direct dyes sales.

Production is a synthetic process by which benzidine or some other starting chemical is reacted with suitable secondary components such as aromatics or amines to produce the dyes. Since the manufacture of dyes is directed toward producing a particular color and not to producing a specific chemical entity, impurities such as benzidine, 4-amino biphenyl, 2,4-diaminoazobenzene, diphenylene, and simidine find their way into the final dye product. If these substances do not interfere with the dyeing process, ordinarily they are not removed. Additional substances, including other dyes, may be required to produce the particular shade or hue desired in a product. Thus, dyes in general represent mixtures of

substances rather than a particular chemical entity. Further complicating supply conditions is the fact that manufacturers may use differing conditions of synthesis, starting materials of different purity, and even different methods to manufacture dyes.

U.S. production of benzidine declined from 700 metric tons in 1972 to an estimated 500 metric tons in 1974, a large proportion of which was for on-site captive use. Production continued to decline steadily after 1974, and in 1976 all large-scale production of benzidine salts in the U.S. were discontinued. Subsequently, only two U.S. companies continued to manufacture benzidine dyes by in situ conversion of hydrazo-benzene to benzidine tetrazonic salt. Although prices were quoted for benzidine compounds as late as 1976, there simply was no longer a market for the material by this time. Relatively small quantities of benzidine remained available for diagnostic testing. Between 1976 and 1981, only 9.2 tons were added to the stock of benzidine available in this country, all from imports into the U.S. in 1976 and 1980*.

The decline in commercial production and availability of benzidine through change to an in situ mode of operation and virtual cessation of imports increased the cost of benzidine-based dyes substantially. Production methods were redesigned to eliminate the need for handling benzidine as a raw material, requiring significant new investment to eliminate worker exposure. These higher costs resulted in most manufacturers ceasing production completely, and those remaining suffering substantial new costs in converting their facilities to in situ status or in switching to a different starting point chemical. In 1974, nine U.S. manufacturers produced benzidine-based dyes (although more than 30 manufacturers in the U.S. produced other direct dyes). Only one manufacturer, Fabricolor, still produces such dyes currently. Some distributors still import benzidine-based dyes for resale in the U.S.

* Source: International Trade Commission, Synthetic Organic Chemicals Yearbook and Imports of Benzenoid Chemicals, 1976-1981.

Since 1974, eight manufacturers who have phased out of the synthesis of benzidine-based dyes have replaced them with substitutes. Initially, these substitutes were o-tolidine and o-dianisidine, the so-called benzidine-congener dyes, or dyes having the same chemical structure. When these substitutes were called into question as potential suspect hazards, other substitutes were turned to, with non-benzidine-based substitutes being particularly in demand.

Production data for benzidine-based dyes as a class are not available in complete time series. Data on sales (production + imports + stock decrease) are available for 1971-5 for fourteen dyes or approximately 70% of the total physical volume of benzidine-based dyes. Thereafter, however, data are only available in the aggregate for three years — 1976, 1978, and 1979. Though later data are not known, it is known that approximately 61 benzidine-based dyes were in production in 1981 for some use(s). Average annual growth rates for the total volume for all fourteen dyes for each year were "fitted" backwards to 1976 aggregate data for production plus imports in order to obtain comparable aggregate estimates for earlier years. Exhibit III shows production plus imports for the general category of benzidine-based dyes compared with the entire class of direct dyes. This Exhibit points out vividly the extent to which benzidine-based dyes have declined as a proportion of their most relevant total category.

Two specific benzidine-based dyes — Direct Black 38 and Direct Brown 95 — have been singled out for special regulatory designation, as described below. Exhibit I above indicated their uses. It is worth noting that Direct Black 38 for many years was the largest selling benzidine-based dye. Since 1979, neither of these two dyes has been domestically produced. Exhibit III shows production and imports for each. The number of manufacturers of these two dyes has declined approximately in tandem with the number of manufacturers of the total category, i.e. from nine (Brown 95) or ten (Black 38) in 1970 to five or six in 1975, two or three in 1977, and one, Fabricolor, beginning in 1979. Domestic production fell to zero during 1979 and has stayed at that level thereafter, according to a Fabricolor spokesman.

EXHIBIT III

PRODUCTION AND IMPORTS OF DIRECT DYES, THE GENERAL CATEGORY OF BENZIDINE-BASED DYES, AND TWO SPECIFIC BENZIDINE-BASED DYES, DIRECT BLACK 38 AND DIRECT BROWN 95 (thousands of pounds)

<u>Year</u>	<u>Benzidine- Based Dyes</u>	<u>Direct Dyes</u>	<u>Direct Black 38</u>	<u>Direct Brown 95</u>
1971	11,223	NA	5,292	532
1972	10,678	39,120	6,701	523
1973	10,133	40,370	6,743	575
1974	6,553	32,920	3,734	341
1975	4,726	26,280	2,168	350
1976	7,036	34,800	3,830	599
1977	NA	31,770	NA	NA
1978	3,312	29,640	1,816	79
1979	600	30,700	327	22
1980	NA	33,220	209	24
1981	NA	38,900	222	21

Source: EPA 1979; CPSC, 1983; HEW, 1980, p. 7; Predicasts Basebook, p. 370.

Note: 1971-6 totals for benzidine-based dyes were based on negative growth rates for a sample of 14 benzidine-based direct dyes fitted to aggregate data for 1976 available from EPA.

As indicated above, one of the categories of use, dyes for home consumption, has also been singled out for specific regulatory attention. Based on CPSC data, there were three manufacturers during the year 1978-9, when 30,000 lbs. were estimated to have been produced and imported, and all used benzidine congener dyes as the major synthesizing chemical (CPSC, 1983, p. 2). At the beginning of 1978, only one manufacturer produced direct benzidine-based dyes, and he discontinued manufacturing during that year, switching to congener dyes. The remaining two producers based their operations on benzidine congener dyes of similar structure. Each of the three was estimated to have an approximately equal share of the market. In late 1980, however, these three producers began to engage in switching behavior:

- The first reported no benzidine congener activity since November, 1980.
- The second reported no manufacture, sales, or distribution of congeners as of January, 1981.
- The third indicated that reformulation from congeners to substitutes would be complete by the end of 1983.

D. REGULATORY HISTORY

There are four phases in the regulatory history of benzidine dyes, and each shall be discussed in order. The first phase consisted of regulation of the benzidine intermediate. It was initially thought that the toxicity of benzidine-based dyes existed solely at the benzidine production stage, not in the use and application of the dyes themselves. To this end, in 1973, NIOSH recommended that benzidine be regulated as a work place carcinogen and late in that year, OSHA proposed and put into effect a strict standard to that effect. The standard was finalized in 1974.

The second phase consisted of regulation of benzidine-based dyes themselves, as toxicity knowledge accumulated that workers exposed to such dyes metabolized these dyes into harmful benzidine levels. This phase began with epidemiological studies published in 1971, 1973, and 1975, reporting that exposure

to benzidine-based dyes produced cancer in humans. In 1977, a milestone NIOSH study of workers exposed to benzidine-based dyes confirmed the metabolic breakdown hypothesis. This study was followed in 1979 by an EPA proposed rule under Section 8(d) of TSCA which required that health and safety studies be furnished for benzidine-based dyes. In early January 1980, NIOSH published an occupational hazard review for all such dyes, and in late December of that year, OSHA followed with a public health hazard alert, which was also extended to the congener dyes, o-tolidine and o-dianisidine.

The third separable phase consisted of regulatory attention to two specific dyes: Direct Black 38 and Direct Brown 95. A 1973 study indicated that dermal exposure to Direct Black 38 could be a serious carcinogen problem for humans. Other earlier studies had raised concern about Direct Black, though not as explicitly. This was followed by a 1975 finding that Direct Black 38 could be carcinogenic in rats. The milestone year for specific dyes was 1978, wherein NIOSH recommended that Direct Black and Direct Brown be treated as carcinogens after rat tests produced rapid tumorigenesis from exposure to them. OSHA followed in 1980 with guidelines for its field personnel to follow when issuing citations for worker exposure to these dyes as well as to Direct Blue 6.

The fourth and last phase consisted of regulatory attention to the home use category. Two major events were relevant here, both occurring at the end of 1980. In December of that year, the OSHA public health hazard alert, mentioned above, which applied to all dyes for home use, both benzidine-based and congeners, was published. Almost simultaneously, CPSC granted a petition to a public interest group to begin rule development to ban consumer dye products containing benzidine-based and congener dyes.

E. ANALYSIS OF REGULATORY IMPACT

The impact of suspect hazard and regulatory designation was examined for four chemical categories: (1) benzidine production; (2) the general category of benzidine-based dyes; (3) specific benzidine-based dyes Direct Black 38 and Direct Brown 95; and (4) dyes for consumer use. Each shall be discussed in order.

1. Benzidine

Exhibit IV shows the relationship between key regulatory events affecting economic activity in production and importation of the benzidine intermediate; and the level of benzidine production/importation for the period 1972-1981.

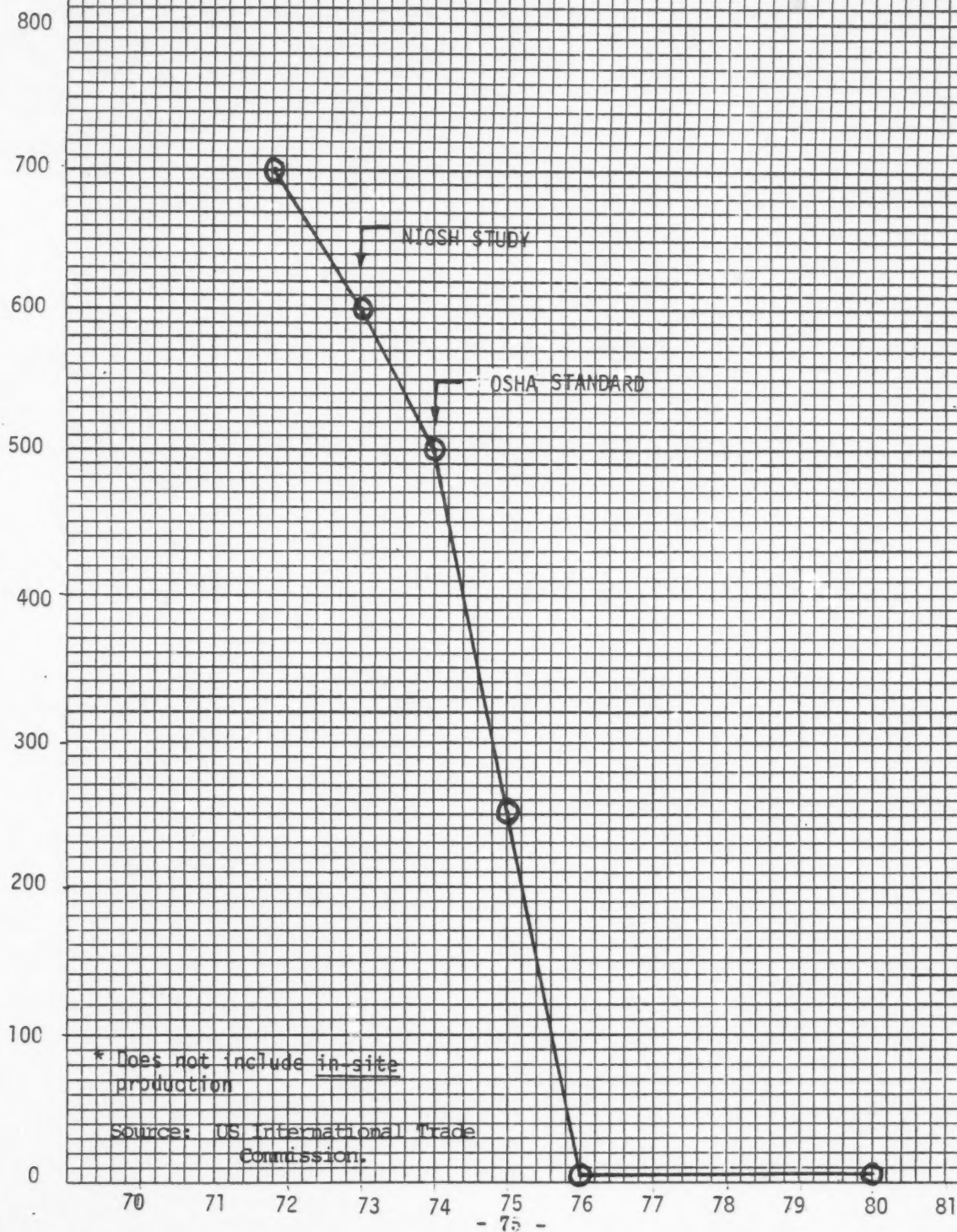
The Exhibit shows that a precipitous drop-off in production and imports occurred in the two years directly after the OSHA regulation was put into effect (1974 and 1975), although a significant secondary drop-off was also noted in the year that NIOSH study results were published (1973). Although some of the decline may have been attributable to the 1974 recession, most secondary sources (USITC, 1981, p. 6; EPA, OSHA) suggest that the cause of the decline to virtually zero levels of commercial utilization of benzidine was the strictness of the new OSHA rule, requiring as it did vertical backward integration into closed-system in situ production of benzidine with an extensive system of worker protections built in. (The precise rate of decline between 1974 and 1976 is not known, so a linear extrapolation was made for 1975. During this period, although data were not available, sales were undoubtedly higher than the total of production plus imports as a result of inventory liquidation).

2. General Category of Benzidine-based Dyes

Three major factors potentially affected activity in the general category of benzidine-based dyes: price and availability of substitutes; the general level of economic activity; and regulatory action and suspect hazard designation.

Price does not appear to be a significant actual explanatory factor for movements in the general benzidine-based dyes category. As indicated above, the prices of benzidine-based dyes on the average have been approximately 25% lower than the price of substitutes. According to Fabricolor, (verbal communication with Mr. E. Angstadt, 6/28/83), substitutes for benzidine-based dyes have a long

EXHIBIT IV
PRODUCTION AND IMPORTS OF BENZIDINE
AND KEY REGULATORY EVENTS*
(metric tons)



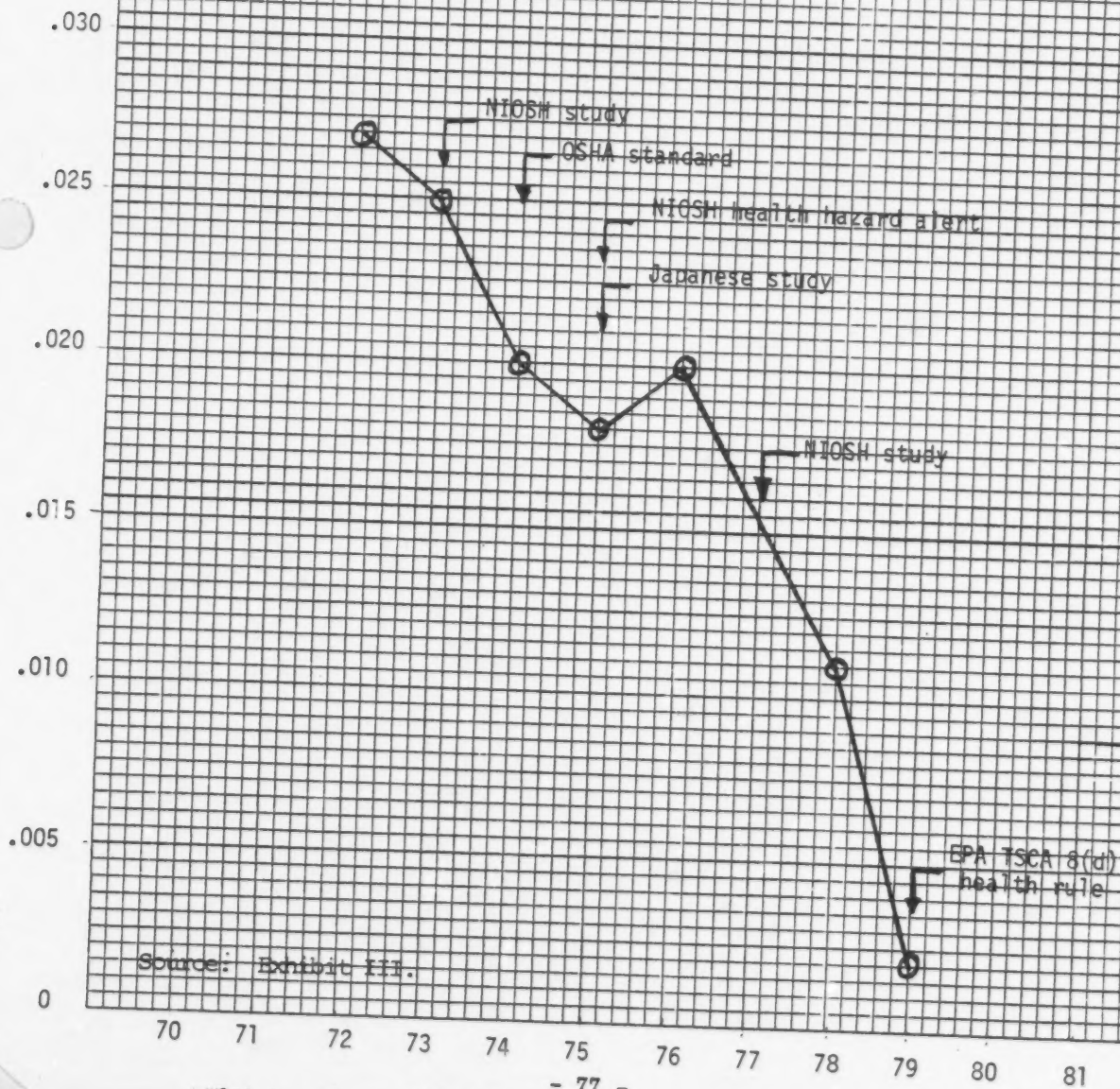
history of being relatively more expensive and inferior in one or more dimensions. For example, at present, five manufacturers sell non-benzidine-based substitutes for what has been historically the largest selling dye, Direct Black 38. Because they are more expensive and frequently offer inferior features, economic behavior of substitutes would not appear to explain the downward trend in the general level of benzidine-based dye production/importation.

Correlation of benzidine-based dye production/importation with general economic activity is shown by comparison of the benzidine-based dye series with changes in activity in the general category of direct dyes, which vary with the general economy's consumption of textiles, leather, and paper (although autocorrelation of the two series occurs because one is a component of the other). To the extent that activity in benzidine-based dyes departs from general economic trends, we may look to regulatory action and designation given that substitutes are not a factor, for an explanation of benzidine-based dye activity.

Exhibit V presents trends in benzidine-based dyes relative to general economic activity (as measured by direct dyes) and appropriate regulatory milestones. Activity in the general benzidine-based category declined significantly relative to total direct dyes, particularly in 1974 and 1975, the time after the OSHA ruling following NIOSH's finding, as well as the 1975 Japanese study. The decline was even greater than the decline in the general direct dye category portrayed in Exhibit III. In 1976, production of benzidine-based dyes relative to total dyes rebounded, tracking and even exceeding the upward trend in direct dyes in that year. After 1976, however, the significant downward trend in benzidine-based dyes relative to general economic activity as measured by direct dyes resumed with a suspect hazard designation milestone occurring in 1975 in the form of confirmation by NIOSH of adverse worker health effects of general benzidine-based dye exposure, and an EPA TSCA 8(d) health rule occurring in 1979.

Thus in general, overall trends in benzidine-based dyes, moving downward relative to the aggregate direct dyes series, appear to be associated with actual regulations and suspect hazard designations, rather than levels of overall direct

EXHIBIT V
 RATIO TOTAL BENZIDINE-BASED DYES
 TO TOTAL DIRECT DYES
 (Production and Imports)



dye activity. In this connection, it is interesting to note that the one year, 1976, when benzidine-based dyes appeared to rebound was the same year in which no additional bad regulatory news for the benzidine-based dye group occurred.

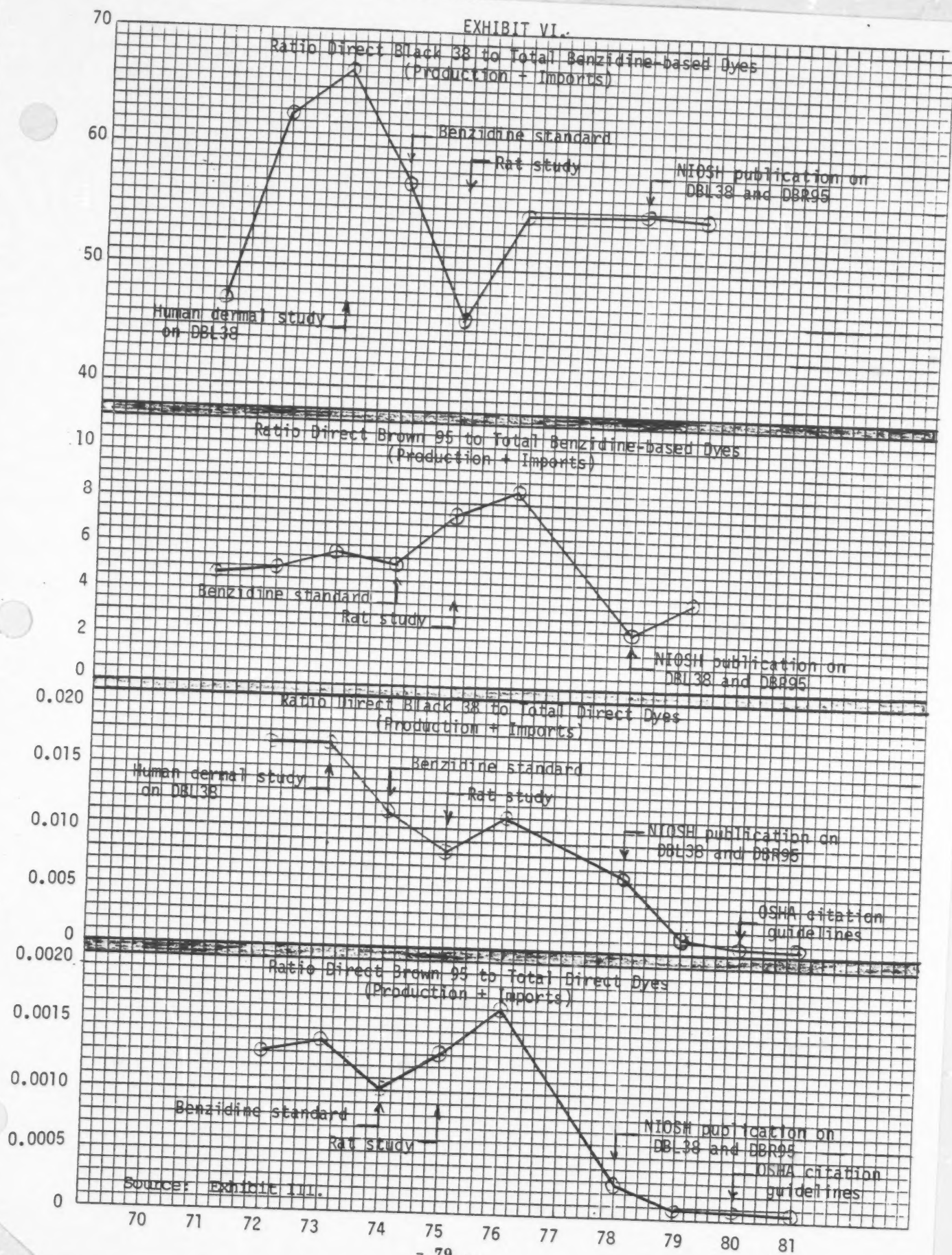
3. Specific Dyes

To explain the movement in specific examples of benzidine-based dyes targeted for regulation, one must examine the same factors described above—general economic activity as shown by direct dyes, and regulation and regulatory designation. In addition, one must also examine trends in the general category of benzidine-based dyes, since specific chemicals in this category may simply reflect movement in the general category rather than their own set of explanatory factors. As above, based on personal communication with the dye expert of the sole domestic producer, Fabricolor, behavior of substitutes is not a relevant explanatory factor here.

Exhibit VI indicates economic activity and regulatory events for two specific benzidine-based dyes for which sufficient data were available for analysis purposes, Direct Black 38 and Direct Brown 95, compared with the time series for the general category of benzidine-based dyes as well as the generic direct dye category. As the Exhibit makes clear, both Direct Black and Direct Brown have significantly declined relative to the general category of direct dyes, Direct Black over the entire period and Direct Brown in the latter period only. In 1976, however, the year of recovery from the recession, the two specific dyes increased their production/importation levels relative to the total for direct dyes.

The relative decline is large for Direct Black in the year of the benzidine standard (1974), and the year of the carcinogen rat findings (1975). A significant decline in Direct Black was also registered between 1976 and 1978, the milestone year of the NIOSH study, and in the following year, 1979. A large (40%) relative decline in Direct Black occurred between 1979 and 1980, the year of the OSHA citation guidelines, which were tantamount to a codification of the 1974 standard in its applicability to this specific dye.

EXHIBIT VI.



Until 1976, Direct Brown gained an increasing relative share of the total direct dye market except for 1974, the year of the OSHA benzidine regulation. From 1976 to 1978, however, when NIOSH made its first carcinogen findings for Direct Brown specifically, this dye began to decline relative to all direct dyes, and continued its relative decline in the next year. From 1979 to 1980, the year of the OSHA citation guidelines, Direct Brown declined an additional 30%.

In summary, movements in the two specific dyes seem to be more closely associated with regulatory events rather than with changes in economic activity as measured by the time series for all direct dyes.

The impact of regulatory activities specific to Direct Black and Direct Brown was also examined. Regulatory activities specific to Direct Black correlate in a mixed way with the decline in Direct Black production/importation. Publication of an adverse 1975 rat study showed a negative impact on activity in this dye from the previous year, but publication of an equally adverse finding in a 1973 human dermal study did not. Publication of the milestone 1978 NIOSH recommendation that this dye be treated as a carcinogen, produced very slight noticeable additional relative decline in this dye beyond that in the overall benzidine-based dye category.

The same mixed pattern of impact of specific regulatory activities is not in evidence, however, with Direct Brown. Direct Brown declined significantly from 1976 to 1978, over and above the decline expected as part of the overall benzidine-based category. The year 1978 was when NIOSH announced that its carcinogen findings for the first time applied specifically to Direct Brown.

Thus, negative regulatory designation applicable to these dyes appears to have had some negative impact on production plus imports. For Direct Brown, significant additional impact appeared in the years immediately prior to the NIOSH milestone. For Direct Black, incremental impact appeared to be significant beyond what would be expected based on its membership in the overall

benzidine dye category. This impact was mainly associated with the human dermal study in 1973 specific to Direct Black.

4. Consumer Use

From a high of 30,000 lbs. in 1978-9, estimated production/importation of benzidine-based and benzidine congener dyes were estimated to decline by approximately 10,000 lbs. each in 1981 and 1982 and to be completely phased out by the end of 1983. According to industry and government (CPSC) observers, this impact has been almost entirely associated with regulatory events. (Chemical Week, 9/82, p. 54; Chemical Business, 6/82, p. 33; CPSC, 1983). These regulatory events occurred at the end of 1980: the OSHA 1980 public health hazard alert for the benzidine congener dyes; and, more importantly, the granting by CPSC of a petition to a public interest group to begin rule development to ban consumer dye products containing benzidine-based and congener dyes.

Thus, trends in consumer use appear strongly, if not entirely, associated with regulatory designation.

SECTION II.4

REGULATORY IMPACT ANALYSIS FOR CADMIUM

The purpose of this summary is to report on the potential market impact of designating cadmium as a suspect toxic hazard. An estimate of such impact depends upon careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. CONSUMPTION AND USE CHARACTERISTICS

Since the end of World War I, the United States has remained the largest user of cadmium. Until 1969, the peak year of consumption, the United States accounted for 50% to 80% of all cadmium consumed. Since 1969, however, cadmium consumption in the United States has experienced a continued decline.

There appear to be four principal use categories for cadmium including both the metal form and compounds, as shown in Table 1.

Table 1. Principal Uses and Consumption of Cadmium

Use	Percent					Apparent Consumption (1982) (metric tons)
	1969	1973	1976	1979	1982 ^e	
Coating and Plating	51	35	40	41	34	1263
Pigments	11	22	15	16	27	1003
Batteries	4	12	26	26	16	595
Plastic Stabilizers	21	20	13	13	15	557
Other	13	11	5	4	8	297
						<u>3715</u>

^e = estimate

Source: USBOM, Mineral Facts and Problems, p. 135.
USBOM, Mineral Commodity Summaries, p. 25 (1982)

The largest use category (34%) is coating and plating used in transportation applications (plating of fasteners, and carburetor and magnetic parts), architectural and precision hardware, electronics and appliance parts, and industrial

machinery. Currently, pigments constitute 27% of cadmium consumption and are the principal end-use of cadmium compounds. Cadmium-based pigments provide many advantages such as high heat stability, color intensity, etc., for applications in plastics, paints, enamels, lacquers, and printing inks. About 16% of cadmium consumed is used in batteries, where cadmium provides the advantages of long life, good performance under wide temperature ranges, maximum current delivery, low operating costs, and low rate of self-discharge. The final principal user category (15%) is plastic stabilizers in both flexible and rigid types of polyvinyl chloride to inhibit degradation of the plastic both during processing and later during exposure to ultraviolet light. Other uses for cadmium are in alloys, chemical, electrical, and electronic industries, as well as in nuclear engineering.

Most uses of cadmium are completely dissipative: less than 5% of all the cadmium currently consumed is recycled. With respect to the four largest uses of cadmium in consumer products, only batteries are recycled for their cadmium content. The low rate of secondary recovery has undesirable consequences in terms of environmental dispersion and future global resource availability of cadmium. (On the other hand, if cadmium were not commercially separated from its major supply sources, zinc and lead ores, it would be dispersed into the environment on a much wider scale in the form of flue particles and other industrial waste products.)

B. SUPPLY FACTORS

There are no ores exclusively mined for cadmium. Cadmium is principally a by-product of zinc production and to a lesser extent of copper and lead production. The total supply of cadmium thus depends largely on activities in the zinc industry and, to a much lesser extent, the lead and copper industries. However, smelter residues, from which cadmium is extracted, are often stockpiled in times of low demand or price, with the result that cadmium production is not always directly related to production of the principal metals. As of 1981, there were four companies producing cadmium metal in the United States (AMAX - Illinois, ASARCO - Texas and Colorado, Jersey Miniere Zinc - Tennessee, and National

Zinc - Oklahoma). This number is down from a total of seven producers in 1979.

Cadmium production now constitutes an integral part of the zinc industry and accounts for about 4% to 10% of income generated from zinc sales. However, from the overall standpoint of zinc producers, cadmium recovery is inadequate to materially affect the marketing or production policy for the entire zinc industry. Hence, there is little incentive to search for ores with higher concentrations of cadmium. Therefore, future supplies of cadmium must depend on better recovery from the present sources, and the discovery and development of other cadmium-bearing ores. The by-product relationship also means that changes in cadmium price are determined chiefly by the supply and price of zinc.

If the United States had to depend solely on its own resources of cadmium, all the domestic cadmium reserves would be consumed before 1990. However, because domestic mine production accounts for about one-fourth of demand, the supply of cadmium should last well beyond 2000 if imported materials continue to supply the remaining three-fourths. The continued viability of the domestic cadmium industry is contingent upon approximately equivalent growth of the zinc industry and no significant decrease in the cadmium content of domestic zinc ores. Up to the present, there have been no reported domestic cadmium supply shortfalls due either to zinc mine strikes or excessive consumption demand.

C. REGULATORY HISTORY

1. Environmental Concerns

Distribution of cadmium into the environment has been a matter of some concern. Such distribution results both from natural processes and as a consequence of human activity. Major sources of cadmium in the environment are processes involved in the extraction, refinement, and production of zinc, lead, copper, cadmium, iron, and steel. Other sources of cadmium include the subsequent conversion of processed cadmium into various consumer products, emissions from use of fossil fuels, use of phosphate fertilizers with a high

cadmium content (cadmium is present in phosphate rocks and is concentrated during production of phosphate fertilizer), wearing of tires, and combustion of lubricating oil. The exact chemical form of cadmium released into the environment and the medium to which it is released depend on the particular industry. Table 2 provides an overview of identifiable releases of cadmium to the environment.

Table 2. Identifiable Releases of Cadmium to the Environment

<u>Source</u>	<u>Percent</u>
A. <u>Direct</u>	
Zinc Mining and Smelting (Air, Water, Tailings)	20
Industrial Uses (electroplating, plastics, waste, scrap)	30
B. <u>Indirect</u>	50
Fossil fuel combustion	
Fertilizer use (phosphate)	
Disposal of sewage sludge	

Source: Derived from Nriagu, Chapter 3.

2. Regulatory Milestones

One of the earliest attempts in the United States to study the effects of continued exposure to cadmium was for industrial workers and was made in 1947. In 1950, 1955, 1961, 1965, and 1969, studies were reported on worker exposure to cadmium in nickel-cadmium battery factories. Studies examining worker exposure to cadmium in other industries using cadmium or its compounds were published in 1963, 1967, and 1974 for plastic stabilizer, cadmium alloy smelting, and electronic applications, respectively. In addition to these and other human epidemiologic studies, a plethora of animal toxicity studies using cadmium in various forms have been published.

In 1941, the American Standards Association (now known as American National Standards Institute, Inc.) recommended an allowable concentration of

0.1 mg/m³ TWA for cadmium and its compounds. This standard in its revised form in 1970 was the basis for the first federal standard published by OSHA on June 27, 1974 for occupational exposure to cadmium fumes and dust. In June, 1975, NIOSH published its concern about possible tumorigenicity of a number of chemicals including cadmium. Then in March 1976, NIOSH also evidenced in published form its concern with the possible teratogenic or mutagenic effects of some chemical agents, including cadmium. In August of that year, NIOSH published a criteria document for a recommended occupational exposure standard to all forms of cadmium. This proposed standard was not designed for the population-at-large, but only for occupational exposure in the processing, manufacture and use of cadmium.

The regulatory actions which followed these occupational concerns during the later 1970s and early 1980s were aimed primarily at specific uses of cadmium. In October 1977, EPA issued a notice of rebuttable presumption against the registration (RPAR) of pesticide products containing cadmium. (Cadmium-containing pesticides account for only one percent of all cadmium used). In February 1978, EPA proposed classification and application criteria for cadmium-bearing solid waste from municipal sewage for disposal on agricultural land. In December 1978, EPA proposed effluent guidelines limiting cadmium contained in process waste water from electroplating operations and effluents from certain mining and ore milling operations. These proposed effluent regulations were finalized in September 1979, with a compliance deadline for late 1982.

EPA also published interim final criteria and guidelines for the disposal of municipal sewer sludge containing cadmium in September and promulgated final regulations effective November 1980. In 1979, the Swedish government decided to ban the use of cadmium for electroplating, as a stabilizer, and as a pigment. This led the IRLG Cadmium Task Group in 1980 to evaluate the need for similar bans in the U.S. An overview of the extensive regulatory activity for cadmium is provided in Table 3.

Table 3. Establishment of Standards and Regulations for Cadmium

1941	ANSI standard for cadmium and its compounds
1946, 1956, 1965, 1967, and 1970	Revisions of the ANSI standard for cadmium
June 1974	OSHA published the first federal standard for occupational exposure to cadmium fume and dust
1973, 1974, and 1975	Further revisions of the ANSI standard for cadmium
March 1976	NIOSH concern about teratogenic or mutagenic effects of cadmium
August 1976	NIOSH published criteria document for a recommended occupational exposure standard to all forms of cadmium
October 1976	Nine federal government agencies initiated a year-long cooperative effort with the electroplating industry to review methods for reducing cadmium pollution and use of alternatives in cadmium electroplating.
October 1977	EPA issued notice of RPAR for pesticides containing cadmium
October 1977	Final workshop and culmination of joint government-industry study of cadmium electroplating
November 1977	Establishment of IRLG Task Group for cadmium
February 1978	EPA proposed guidelines for the disposal of municipal sewage sludge containing cadmium on agricultural land
December 1978	EPA proposed effluent guidelines limiting the amount of cadmium in waste water discharges from electroplating operations and effluents from certain mining and ore milling operations
September 1979	EPA published final cadmium waste water regulations with a compliance deadline of late 1982
September 1979	EPA published interim final guidelines for cadmium-containing sludge disposal
1980	IRLG evaluated the need to ban the use of cadmium in all its major applications
November 1980	EPA final regulations on disposal of municipal sewage sludge became effective
1982	Compliance deadline for EPA cadmium waste water regulation

D. ANALYSIS OF REGULATORY IMPACT

Based on the preceeding summary of environmental concerns and regulatory events affecting cadmium and cadmium compounds, it is apparent that regulatory scrutiny has focused on two aspects of cadmium; the refining/smelting operations for production of primary cadmium and cadmium electroplating operations. However, because a large part of this regulatory scrutiny is not user-specific, manufacturer and user behavior might have been affected in all major cadmium use categories. Trends in cadmium production and two major use categories—electroplating and pigments—will be examined to assess the impact of specific suspect hazard and regulatory concerns and events. These two major use categories account for 61% of total cadmium demand. Other use categories for cadmium will not be considered in this analysis because of a paucity of publicly-available information.

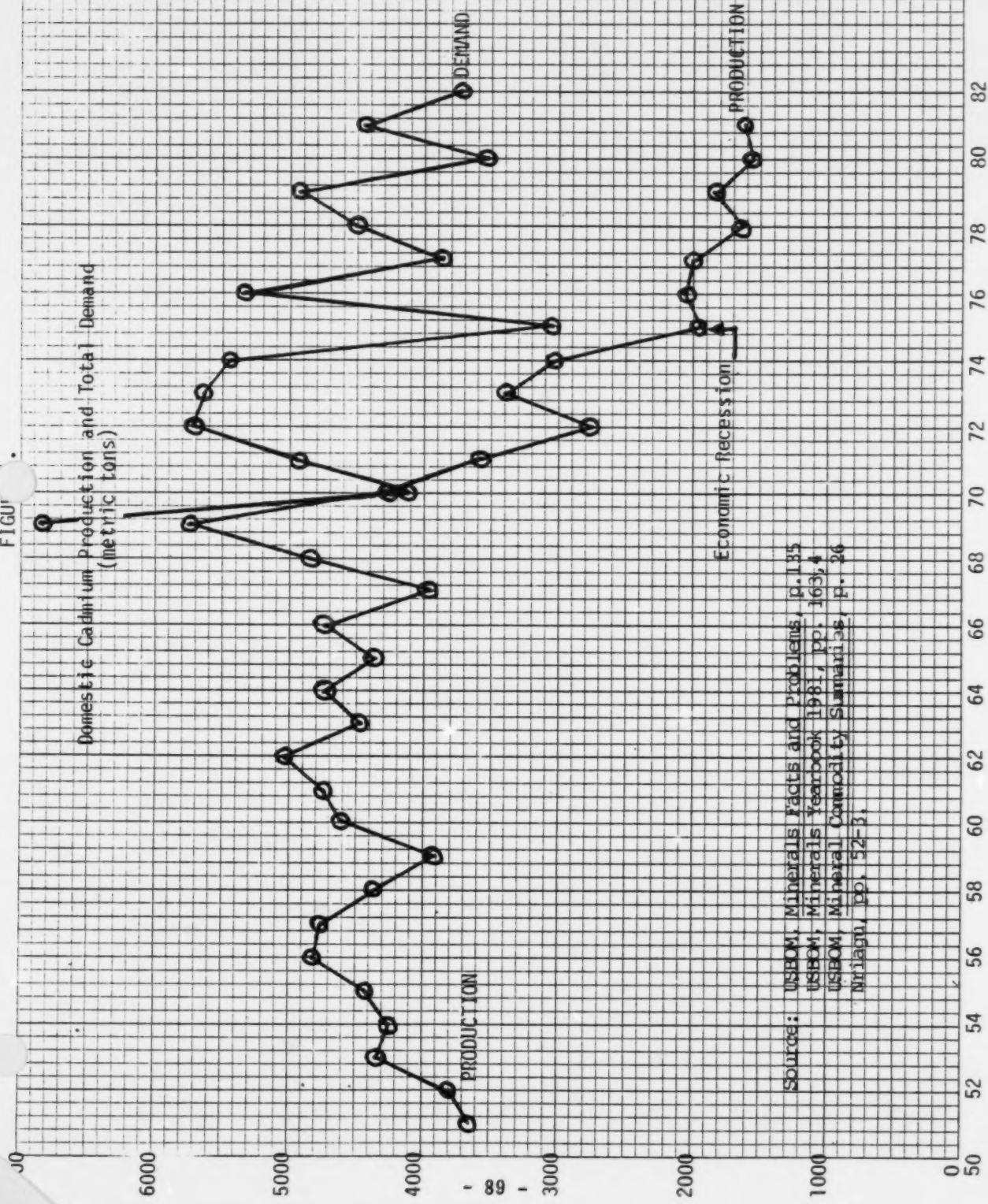
1. Cadmium Refining

As noted earlier above, cadmium production is largely a function of zinc production. The historical pattern of cadmium supply has tended to reflect not only the amount of zinc produced but also the method of zinc production. In the early 1900s, a sharp rise in the amounts of cadmium produced followed the introduction of new processing methods and a great demand for military purposes. A further 45-fold increase world-wide occurred in the period between the world wars. More recently, both domestic and world-wide cadmium production increased to an all-time high figure in 1969 and has been in decline ever since. Figure 1 provides a picture of total domestic cadmium production.

Before this peak and decline, cadmium production remained fairly constant through the 1950s and 1960s. It could be hypothesized that an observed decline in cadmium concentrations in zinc ore could account for the post-1969 decline, but it has been reported that lower cadmium content in zinc ores has been

FIGURE 1

Domestic Cadmium Production and Total Demand
(metric tons)



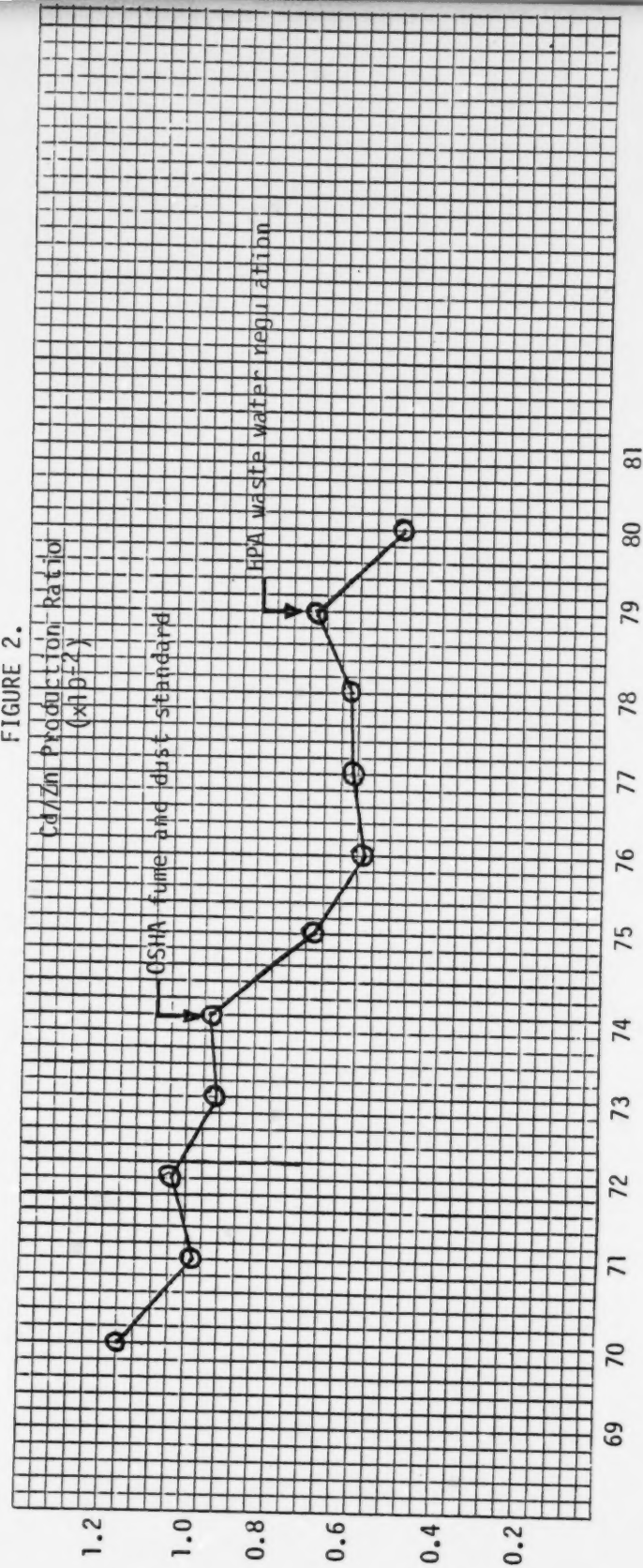
Source: USBOM, Minerals Facts and Problems, p. 135
 USBOM, Minerals Yearbook 1981, pp. 163, 4
 USBOM, Mineral Commodity Summaries, p. 26
 Nriagu, pp. 52-3.

offset by improvements in cadmium recovery methods (Nriagu, p. 50). Between 1973 and 1979, the recovery rate remained fairly constant, averaging 4.56 kgms cadmium per metric ton of zinc produced. Using this average to be an indicator of relatively constant cadmium recovery efficiency (possibly achieved by recovery efficiency advancements being off-set by reduced cadmium concentrations in zinc ore), it is interesting to observe the downward trend in the ratio of domestic cadmium production to domestic zinc production, shown in Figure 2. Two sharp declines are apparent, coinciding with the establishment of the occupational exposure standard to cadmium fumes and dust in 1974 and the waste water effluent regulation for cadmium in 1979. Although the general economic recession of 1975 brought cadmium production down, as shown in Figure 1, this would not account for the total drop, for zinc production (which, has applications that are similar to, if not substitutable for, cadmium) did not decrease proportionately, as indicated by the declining cadmium/zinc ratio for 1975 in Figure 2.

Given that domestic cadmium production supplies only 20% to 25% of domestic demand, it is necessary to look at trends in cadmium imports before a correlation between regulatory scrutiny and producer behavior might be suggested. The trend in cadmium imports relative to domestic production is shown in Figure 3. If the increasing trend in cadmium imports were superimposed on the downward trend in domestic production, it might appear initially that imports simply displaced domestic production to meet what is a picture of the fluctuating but secularly declining domestic demand presented in Figure 1. A relatively constant ratio of imported to domestic prices, as shown in Figure 4, indicates there has been no economic advantage explaining the relative rise in imports.

Additional insight into the nature of the domestic production decline is obtained by examination of the import profile trend in Figure 5. This Figure shows that there has been a substantial reduction in ore imports, indicating a marked preference on the part of domestic cadmium suppliers to reduce refinery operations. In this Figure, it is also interesting to note the sharp change in both curves at the time of the first regulatory event, 1974.

FIGURE 2.



Source: Predicasts Basebook, pp. 473, 479.

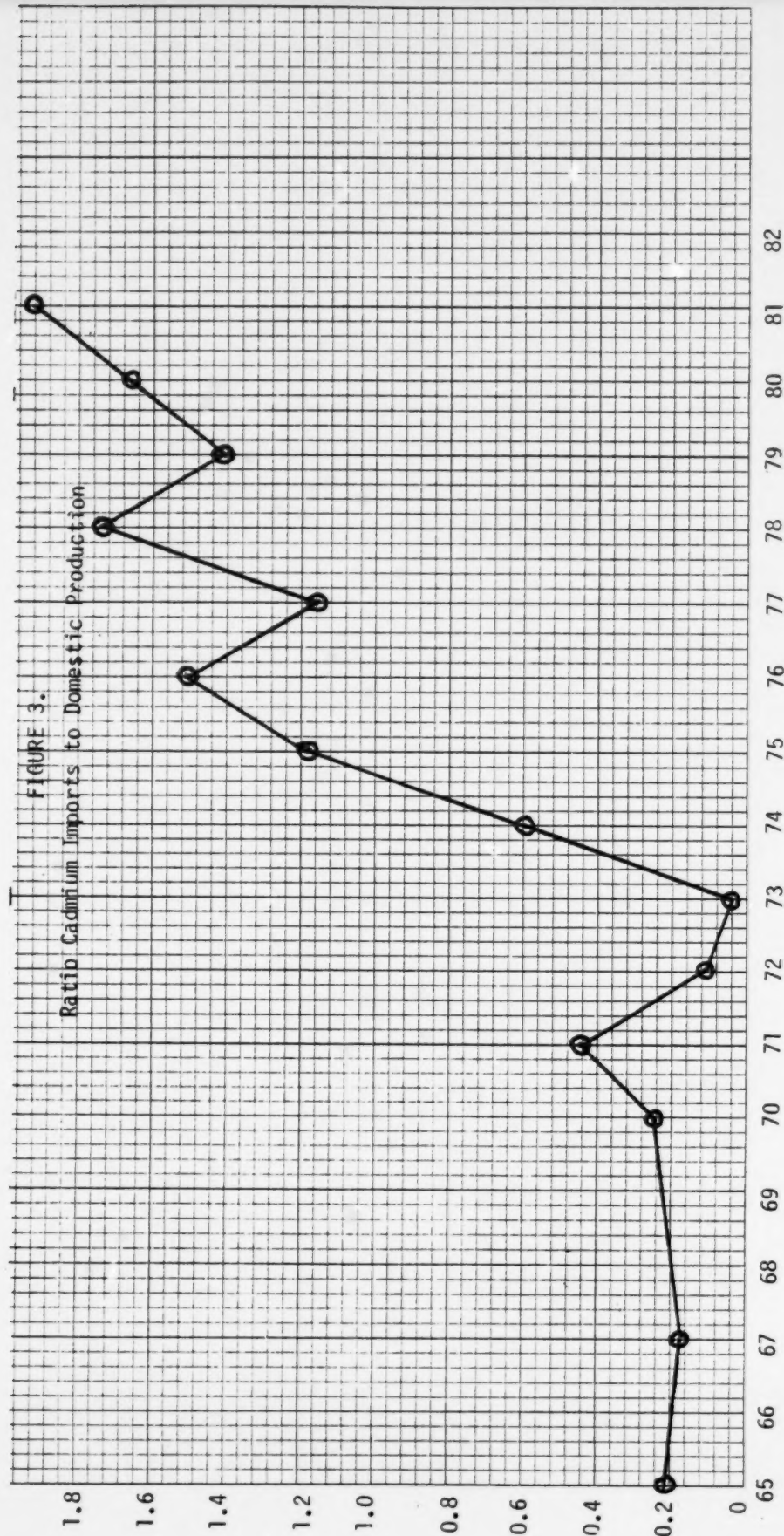
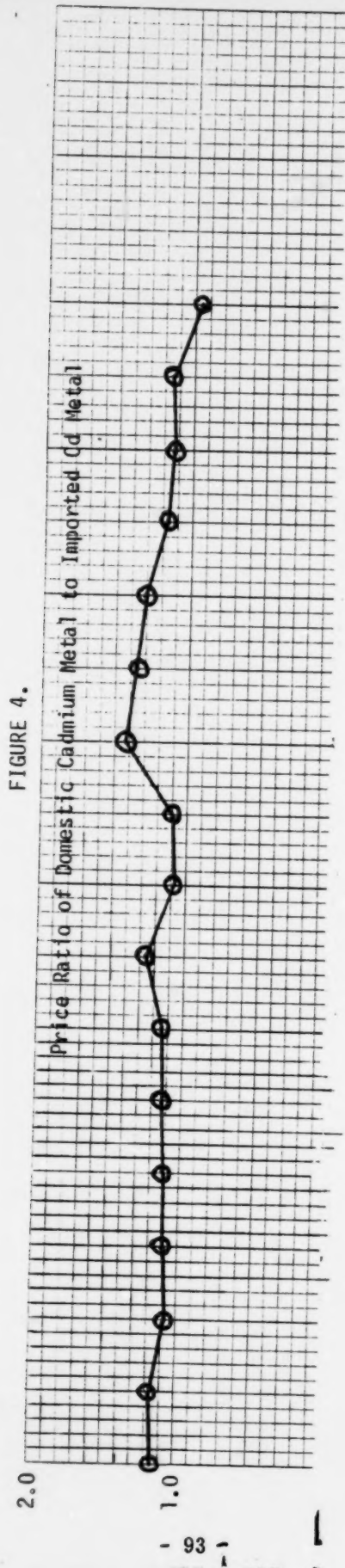


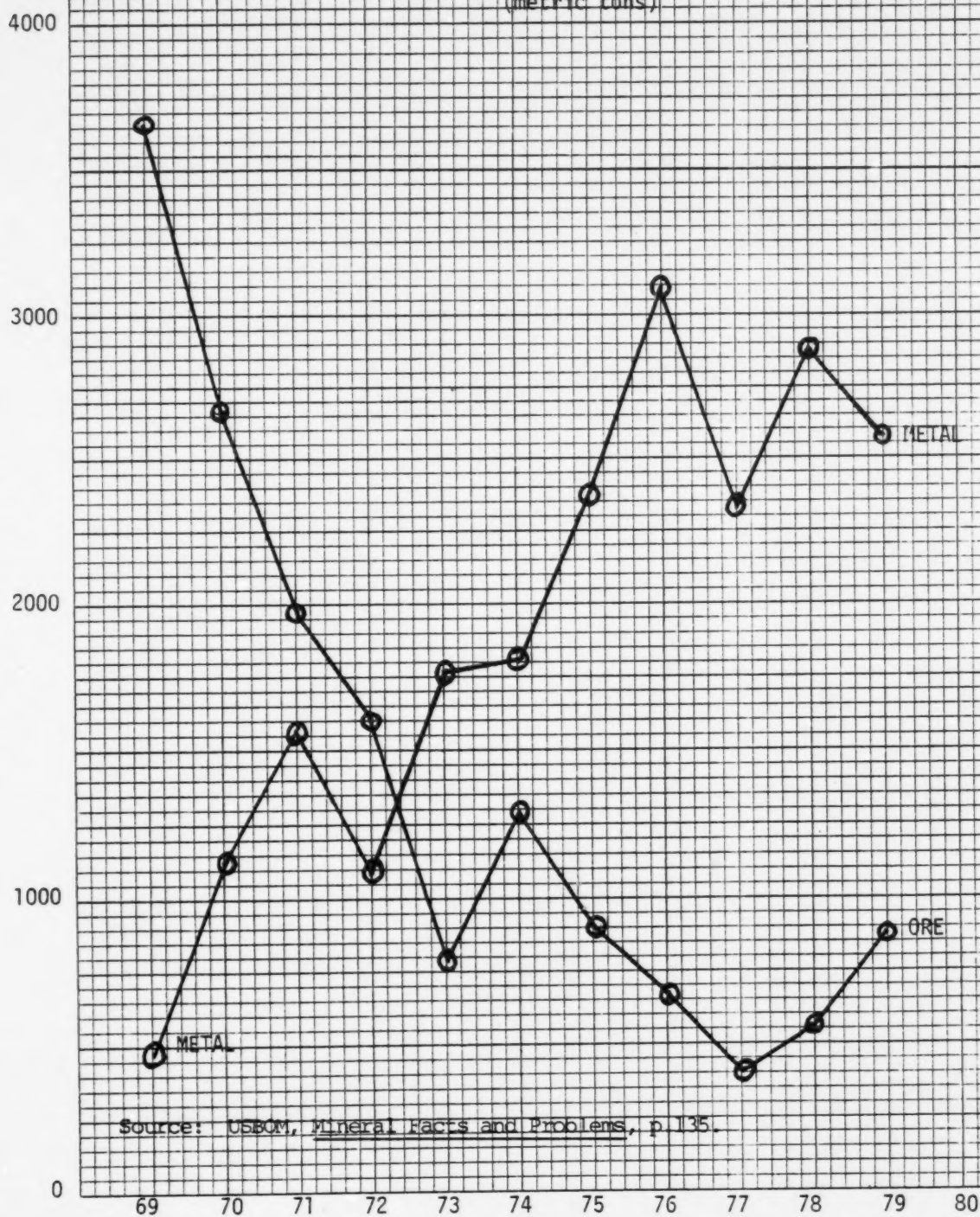
FIGURE 3.
Ratio Cadmium Imports to Domestic Production

Source: Predicasts Basebook, p.479.



Source: Chemical Marketing Reporter

FIGURE 5.
Cadmium Imports - Ore and Metal
(metric tons)



Source: USBOM, Mineral Facts and Problems, p. 135.

Thus, examination of trends in the quantity, price, and profile of domestic and imported cadmium production appears to make it clear that regulatory milestones, as marked by 1974 and 1979, correlate with marked changes in producer behavior. Other economic considerations do not appear to offer adequate explanations for the observed trends. Not only does the coincidence of actual regulatory designations with significant changes in production trends suggest a correlation between regulatory scrutiny and producer behavior, but production behavior during the pre-regulatory suspect hazard designation periods also supports the correlation hypothesis. Decreases in domestic production (Figure 1), ore imports (Figure 5), and the increases in metal imports (Figure 5) started in 1969 and 1970 at the time in which the basis for the 1974 OSHA regulation was published by ANSI. The 1974 regulatory designation acted to reinforce the behavioral change of cadmium refiners in reducing cadmium recovery operations and importing more primary metal.

2. Cadmium Pigments

Cadmium compounds (cadmium sulfide and cadmium selenides) are extensively used as pigments in a wide variety of products, especially plastics (60% to 80%), ceramics (10%), and paints (10%). Cadmium pigments range in color from primrose through golden yellow to red and maroon. Advantageous features of cadmium pigments include: (a) high indices of refraction, giving the appearance of richer, deeper colors; (b) purity of shade and brilliance; (c) excellent heat resistance up to 600°C; (d) good chemical resistance; (e) easy dispersability; and (f) good light and weathering resistance. It is clear from these unique properties why cadmium compounds are choice pigments in many applications.

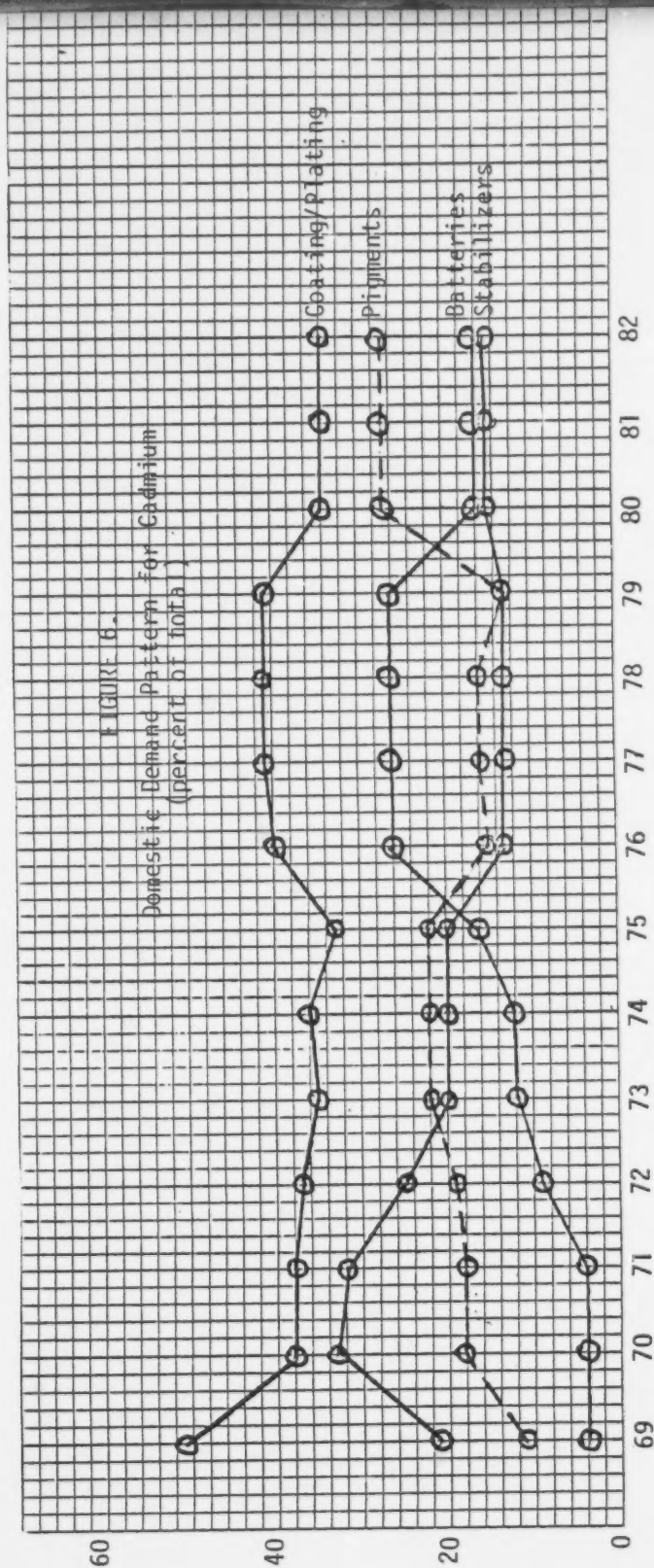
Substitutes for cadmium pigments are ferric oxides, hydrated ferric oxides, and lead and zinc chromates. However, the fact that prices of cadmium pigments (5.60 - 57.10 \$/kg in 1977 and 7.12 - 21.25 \$/kg in 1980) are considerably

higher than these substitutes (0.49 - 2.69 \$/kg in 1980) suggests that cadmium pigments are not substitutable in some applications (Kirk-Othmer, v. 4, p. 407; v. 17, p. 799). For example, these substitutes lack the heat stability especially important in high-temperature molding of plastics and also are somewhat lacking in brilliance.

An overview of cadmium demand for the pigments use category relative to total cadmium demand is provided in Figure 6. From this trend, it appears that the demand for cadmium pigments has risen recently in spite of the environmental concerns over cadmium. A better indication of this demand is found by looking at the trends in cadmium pigment demand juxtaposed with substitute pigment demand, after adjusting both curves to total inorganic pigment demand, thereby substantially reducing the influence of exogenous economic factors (such as recessions, etc.). Figure 7 shows the relative production patterns for cadmium pigments (sulfides and sulfo-selenides) and aggregated substitutes (synthetic iron oxides and chromates). The demand for both cadmium pigments and substitutes has been relatively constant as a percent of total inorganic pigment production, implying that the regulatory scrutiny over cadmium had little or no impact on cadmium pigment manufacturer behavior. A possible explanation for this phenomenon might be that the actual pigment manufacturing process is not known to pose health or environmental problems in terms of nuisance dusts or waste water effluents. According to the Dry Color Manufacturers Association, cadmium pigments, based on available information, seem to pose no known health problems (Kirk-Othmer, v. 17, p. 800). Therefore, in the absence of known cadmium pigment hazards, and pigment-specific regulatory scrutiny, manufacturers have not altered their behavior in terms of production changes and substitution.

3. Cadmium Plating

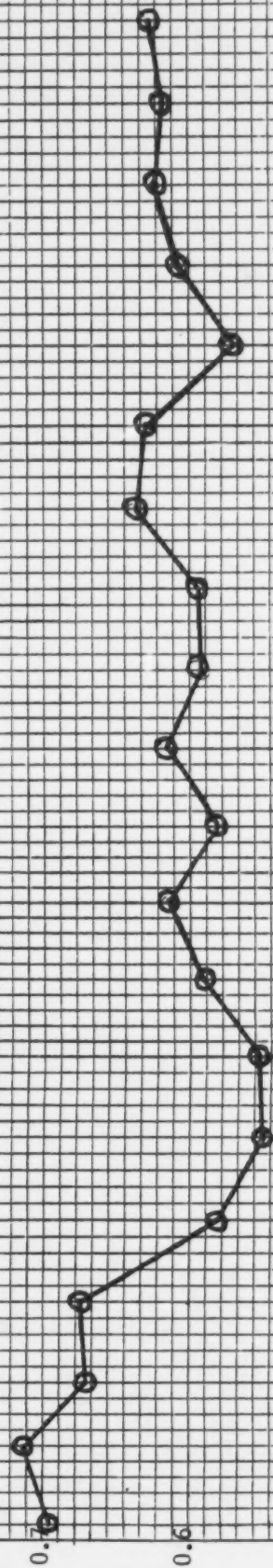
Coating and plating is the largest application category for cadmium, constituting 34% of total cadmium demand in 1982. Practically all cadmium plating is done by electrodeposition and is used extensively in the automotive, aircraft, electronic and appliance industries, among others.



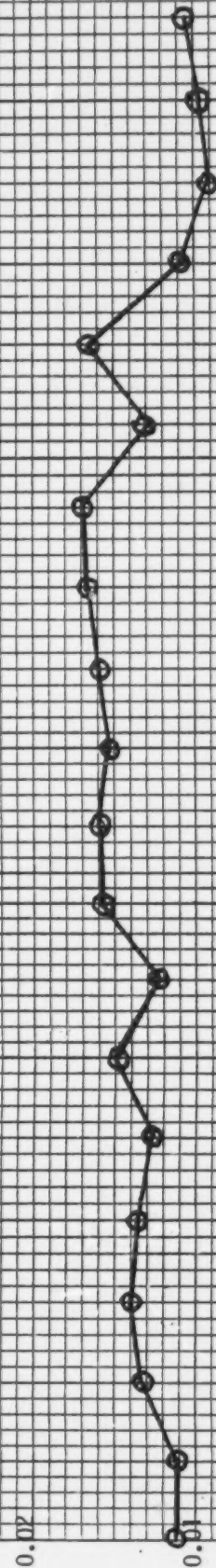
Source: USBOM, Mineral Facts and Problems, p.135 (1969-79)
 USBOM, Minerals Yearbook 1981, p. 163,164 (1980-81)
 USBOM, Mineral Commodity Summaries, p.26 (1982e).

FIGURE 7

A. Ratio Substitute Pigment Production to Total Inorganic Pigment Production



B. Ratio Cadmium Pigment Production to Total Inorganic Pigment Production



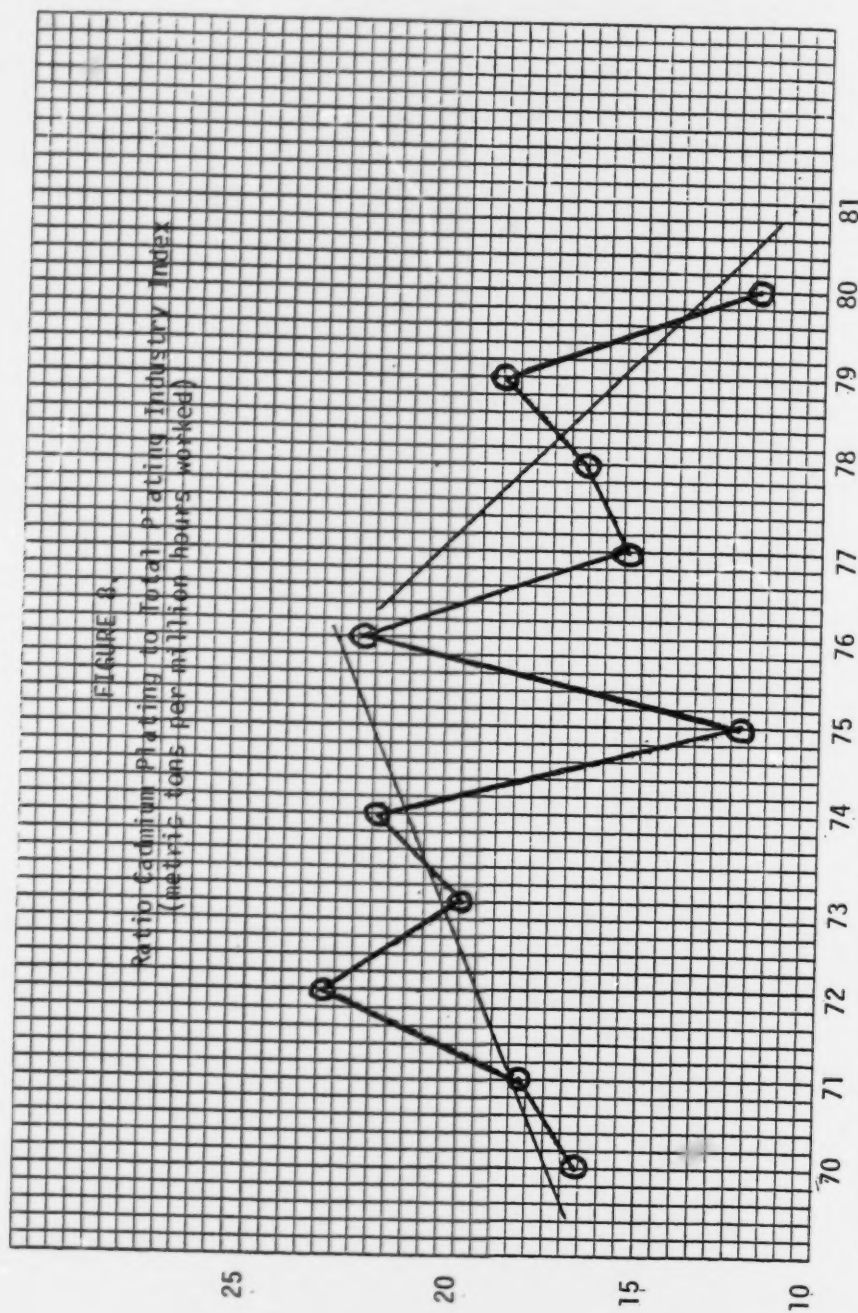
Source: Derived from SHI, PR: 520.50900B, 520.5160B.

Properties of cadmium metal that have led to its widespread use in electroplating include: (a) low contact resistance; (b) ready deposition on intricately shaped objects; (c) good corrosion resistance to alkali and seawater; (d) good solderability of plated parts; (e) high ductility; (f) long coating life; and (g) the ability to protect steel from corrosion.

The trend in cadmium plating, along with the other primary use categories, is shown in Figure 6. This Figure shows that this application category has remained nearly constant as a percent of total cadmium demand. In terms of metric tons of cadmium, the plating demand has then fluctuated in phase with the total domestic demand for cadmium (Figure 1). Figure 8 provides more insight into the use of cadmium for electroplating applications. Using an index for total electroplating activity, cadmium's share of the electroplating market was increasing up to recessionary 1976; then exhibited an erratic downward trend from 1976-80. This change is illustrated by the two best-fit curves in the Figure.

Substitution of the metals such as zinc for cadmium in electroplating applications might offer one explanation for the downward trend after 1975 in Figure 8, but it has been reported that except when the deposited metal is very expensive, e.g. gold, the actual cost of the deposited metal is generally considered to be a minor factor in the total cost of plating. Overhead and labor are the major factors. It is more important, economically, to deposit the required plate quickly and satisfactorily (Kirk-Othmer, v. 8, p. 835). Therefore, the demand for cadmium in plating applications should be widespread because of its favorable inherent characteristics.

Regulatory concerns and events offer a more acceptable explanation for the recent decreasing use of cadmium in plating applications. Concern for cadmium pollution from electroplating operations first became evident in 1976 with initiation of a government/industry cooperative study. In the late 1970s, more papers and reports on various methods of reducing or eliminating contaminants in waste water effluents appeared in the journals devoted to the



Source: USBOM, Mineral Facts and Problems, p.135 (1970-79)
 USBOM, Minerals Yearbook 1981, p. 163-164 (1980)
 Predicasts Basebook, p. 516.

electroplating industry than on any other subject (Kirk-Othmer, v. 8, p. 836). This growing awareness and recognition of the toxic effects of cadmium in plating operations resulted in the development of several patented techniques for removing cadmium from industrial effluent (e.g. AMAX Inc., 1977, and U.S. ERDA, 1977). Then in late 1978, effluent guidelines were proposed, followed by a final waste water regulation in 1979 with a compliance date of 1982. The impact of this pre-regulatory designation period (1976-1979) on the use of cadmium in plating operations seems to have caused operators to modify their behavior and reduce their demand for refined cadmium. Because of the 1982 compliance date for the actual regulation, no assessment can be made of the difference in behavior associated with the pre-regulatory suspect hazard designation period and the period following actual regulatory designation. However, it is evident that the pre-regulatory threat of suspect hazard designation may have had considerable impact on the electroplating use category. If new, highly efficient pollution controls are adopted in electroplating operations to meet the 1979 regulation, the demand for cadmium in this use category could level-out or expand moderately, or, on the other hand, continue to decline because of improved cadmium waste recovery and recycling efficiencies.

E. SUMMARY

In summary, cadmium has been subject to a quite extensive regulatory history beginning in the early 1970s. This regulatory scrutiny has been in the form of both actual regulatory events (1974 and 1979) marking the implementation of cadmium standards, and pre-regulatory suspect hazard designation consisting of publicly announced concerns and regulatory proposals (1970-1974 and 1975-1979) for both cadmium refining and principal use categories.

To assess the impact of this regulatory scrutiny, trends in the two principal use categories—cadmium pigments and electroplating—and in the production and use of cadmium were examined together with supply factors for cadmium ore refining.

After considering exogenous economic factors, it was found that cadmium producer/user behavior appeared to change as a result of changes in the regulatory environment. However, this environment was focused on hazards from cadmium refining and cadmium electroplating, not the cadmium pigment use category. This emphasis motivated cadmium refiners to reduce domestic refining operations in favor of importing primary refined cadmium metal and also resulted in a changing use profile for cadmium so that substantial growth occurred (11% to 27% from 1969 to 1982) in the less- or non-regulated pigments application, with a concomitant reduction in the more regulated electroplating use category.

SECTION II.5

REGULATORY IMPACT ANALYSIS FOR CHLOROFLUOROCARBONS

The purpose of this summary is to report on the impact of designating chlorofluorocarbons as suspect toxic hazards. An estimate of such impact depends on careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. INTRODUCTION

As a class of chemical substances, chlorofluorocarbons (CFCs) are unique because they are chemically very unreactive, nearly odorless, nonflammable and generally nontoxic or of low toxicity. CFCs are here being considered as suspect toxic substances because of an indirect link that has been noted between atmospheric CFC contamination and increased incidences of human skin cancer. Scientific evidence has indicated that CFCs destroy the ozone layer of the atmosphere, thereby increasing ultraviolet radiation exposure. Many scientists have concluded that a number of adverse human health effects, biological effects, and climate effects would result from such increased exposure. These findings, while the subject of considerable controversy, have constituted the major basis for regulatory concern with CFCs.

B. CONSUMPTION AND USE CHARACTERISTICS

Because of their inherent chemical properties, CFCs are in demand for a broad range of domestic and industrial uses and are manufactured in quantities of millions of pounds. Four principal use categories currently account for over 80% of CFC consumption: aerosols, refrigerants, foam-blowing agents, and solvents. Table 1 shows the changing principal use profile for CFCs.

Table 1. Principal Uses and Consumption of Chlorofluorocarbons

<u>Use</u>	<u>Percent</u>					
	<u>1972</u>	<u>1974</u>	<u>1977</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>
Aerosols	50	52	22	2	2	2
Refrigerants	28	29	43	47	48	46
Blowing Agents	7	9	14	19	17	17
Solvents	5	NA	10	13	14	16
Other (Plastics, Exports, Misc.)	10	10	1	19	19	19

Source: Derived from CEQ/FCST, p. 8; IRLG; Stoel, p. 15.

CFCs first came into use in the early 1930s as refrigerants in mechanical vapor-compression systems. These products, which were nonflammable and had low toxicity and chemical reactivity, were prime substitutes for materials previously used as refrigerants (sulfur dioxide and ammonia) because they evaporated rapidly and were liquified quickly when compressed. Ammonia is still used in some commercial applications but CFC-11 (CCl_3F), -12 (CCl_2F_2), and -22 (CHClF_2) are estimated to account for over 90% of refrigerants used in the U.S.* The most frequently used (56% of U.S. refrigeration) is R-12, used as the refrigerant in large building systems. R-22 is used (30%) in residential and commercial air conditioning and refrigeration and in food storage and display where lower temperatures are required.

The use of CFCs in aerosols began during World War II after researchers at the U.S. Department of Agriculture found that the dispersal of insecticides as fine aerosols greatly increased their effectiveness. Aerosol products were first introduced on the consumer market in 1947, following the successful development of reliable pressurizing and delivery systems during World War II.

* The numbering system for chlorofluorocarbons is one used by U.S. industry which, by a complex set of rules, indicates the number of each type of atom in the compound. In all industries other than refrigeration, the CFCs are given an F prefix (fluorocarbon) while in the refrigeration industry the compounds have an R prefix (refrigerants). In addition, certain company trademark names such as Freon[®] are used. Thus, CFC-11, F-11, R-11, and Freon-11 are the same compound.

When low-pressure valves and nozzles were developed, CFCs-11 and -12 became standard propellants for dispensing aerosols. Hundreds of personal, household, and commercial products were introduced in aerosol form, and although many propellant systems are employed, CFCs were the most widely used before becoming subject to environmental concerns of the mid-1970s. Of these, CFC-11 and -12 again accounted for over 90% of the chlorofluorocarbons used in the aerosol industry. CFC propellants were used in personal, household, and industrial aerosol products such as hair sprays, antiperspirants, room deodorants, cleaners, pesticides, paints, etc.

CFCs are also used as foam-blowing agents in the manufacture of foams made from polyurethane, polystyrene, and polyolefin forming the cellular structure of these foams. Other types of plastic foams (primarily vinyl, urea, phenolic, and epoxy foams) are produced in much smaller quantities, and do not typically involve much usage of CFC blowing agents. CFCs are considered essential in achieving the low thermal conductivity required for insulating foams and in preparing soft flexible urethane foams. It is estimated that CFC-11 and -12 constitute over 90% of the CFCs used in plastic foams (EPA, 1976, p. 10).

Solvent and cleaning applications represent areas in which CFCs play a relatively minor role both with respect to the total quantity of solvents used and to the overall consumption of CFCs among the four major use areas. Two CFCs are used almost exclusively in this application, CFC-11 (10%) and CFC-113 (90%) and represent only approximately 5% of the total solvents used for cleaning. The use of CFCs in the cleaning field is concentrated in the electrical and electronics industries for the defluxing of printed circuit boards and the cleaning of electronic parts, electric motors, and delicate electronic and scientific instruments. The solvents are also used to clean metal, glass plastics, and electroplated manufactured articles.

Almost all possible combinations of carbon, hydrogen, fluorine, and chlorine have been prepared for the lower aliphatic organic compounds (e.g.

methane and ethane) as a consequence of the development of these significant uses for CFCs. Table 2 shows the chemical formula and use for a number of CFCs.

Table 2. Chemical Formula and Use of Selected Chlorofluorocarbons

<u>CFC</u>	<u>Formulate</u>	<u>Use</u>
*CFC-11	CCl_3F	Propellant, Refrigerant, Blowing Agent, Solvent
*CFC-12	CCl_2F_2	Propellant, Refrigerant, Blowing Agent
*CFC-13	CClF_3	Refrigerant
CFC-14	CF_4	Propellant, Refrigerant
CFC-22	CHClF_2	Propellant, Refrigerant, Solvent, Polymer Intermediate
CFC-23	CHF_3	Refrigerant
*CFC-113	$\text{CCl}_2\text{FCClF}_2$	Propellant, Refrigerant, Blowing Agent, Dielectric Fluid
CFC-115	CClF_2CF_3	Propellant, Refrigerant, Dielectric
CFC-116	CF_3CF_3	Dielectric Gas
CFC-500	$\text{CCl}_2\text{F}_2/\text{CH}_3\text{CHF}_2$ (73.8/26.2 wt. %)	Refrigerant

* Most potentially hazardous to the atmosphere
Source: Derived from CEQ/FCST, pp. 84-87.

C. SUPPLY FACTORS

CFCs are produced by six companies in the United States; E.I. duPont de Nemours, Allied Chemical, Kaiser Aluminum and Chemical, Pennwalt Chemical, Racon, and Union Carbide. U.S. production was increasing at an annual rate of between 10%-20% until 1975, at which time decreases in both CFC-11 and -12 production brought to an abrupt stop the rapid growth. Table 3 presents

production data for the CFCs. No supply shortfalls or restrictions have been reported. Imports of CFCs are negligible compared to exports and are not an important factor in this analysis.

Table 3. Domestic Production of Chlorofluorocarbons (mill. lbs.)

<u>Year</u>	<u>CFC-11</u>	<u>CFC-12</u>	<u>Other¹</u>	<u>Total</u>
1969	72	166	NA	238
1961	91	173	NA	264
1962	124	207	33	364
1963	140	217	48	405
1964	148	228	56	432
1965	170.5	271.4	72	513
1966	170	286	73	529
1967	182.2	309.7	81	573
1968	204	326	72	602
1969	239	368	71	678
1970	244.5	375.4	73	692
1971	257.9	389.6	80.2	728.2
1972	299.6	439.2	80	819
1973	333.8	488.8	136	959
1974	341.0	487.4	141	969
1975	269.6	393.1	132	795
1976	256.1	393.9	(125.8)	774.9
1977	212.6	358.3	(123.7)	699.6
1978	193.7	327.1	205	726
1979	167.1	293.9	(143.3)	604.3
1980	158.1	295.0	(140.7)	593.8
1981	162.7	325.5	(164.1)	652.3
1982 ^e	149	280	NA	429

^e estimate

¹ Numbers in parentheses are for CFC-22 production only.

Source: U.S. International Trade Commission, Synthetic Organic Chemicals.

D. REGULATORY HISTORY

1. Environmental Concerns

Fluorocarbons can be released into the atmosphere at any stage in the processes of production, transportation, storage, and use.

Emissions during production have been estimated seldom to exceed 1% release, limited to small mechanical leakage and miscellaneous venting factors. Transportation and storage are conducted under completely closed systems meeting established specifications for pressure, and also are estimated to account for less than 1%.

Before the regulatory events of the mid-1970s, increasing quantities of CFCs were released into the atmosphere, mainly through use as propellants in aerosol products, but also as refrigerants, and as foaming agents and solvents in industrial processes. Use of CFCs as propellants results in complete and immediate release to the atmosphere.

In refrigerant uses, the emission of CFCs is somewhat delayed. Losses from this general use may occur from scrapped, junked, or abandoned prefabricated-type refrigeration units, from recharging or replacing large commercial units, or during manufacture of sealed-type units. Some leakage also occurs gradually in certain units, e.g., in automobile air conditioning, where recharging to replace leakage typically is required about every 3 to 4 years. Eventually, at the time for disposal, all the CFCs used will be lost.

As a foam blowing agent, the largest usage of CFCs is in the manufacture of rigid polyurethane foams, mainly for thermal insulation. Because a substantial portion of the CFC vapors are trapped within the closed cells of rigid urethane foams, emissions to the atmosphere are significantly lower than annual consumption. Flexible urethane foams are the second largest user of CFC blowing agents. Virtually all of the CFCs used in preparing flexible foams are lost to the atmosphere soon after manufacture. A few other plastic foams consume small quantities of CFCs, although most other foams employ other means of foam generation. Almost all CFCs used in styrene, olefin, and miscellaneous foams diffuse promptly into the atmosphere.

The loss of CFCs to the atmosphere from applications as a solvent and cleaning agent is dependent on the recovery efficiency of the operation (usually

averaging around 80%). Therefore, it is estimated that 20% of all CFCs consumed in this use category are emitted to the atmosphere.

Table 4 provides an overview of identifiable releases of CFCs to the environment.

Table 4. Identifiable Releases of CFCs to the Environment

<u>Source</u>	<u>Percent of Total Consumption (Prior to Regulatory Concern)</u>	<u>Percent Emitted During Use</u>	<u>Percent of Total Consumption Emitted</u>
A. Immediate	57-84	91-93	52-78
CFC Production	NA	1	NA
Transportation	NA	0-1	NA
Aerosol Propellants	50-70	100	50-70
Foam Blowing Agents (Flexible Foams)	1	100	1
Solvents	6-8	20	1-2
Other	0-5	0-100	0-5
B. Delayed	31-45	84-87	26-39
Refrigerants	21-28	100	21-28
Foam Blowing Agents (Rigid Foams)	10-12	50	5-6
Other	0-5	0-100	0-5

Source: Derived from Table 1 and CEQ/FCST, pp. 92, 93.

Inspection of the last column in this Table makes it apparent that the major sources of atmospheric emission (before regulatory concern) were associated with uses of CFCs as propellants and refrigerants. In absolute terms, approximately 80% of all CFCs released to the atmosphere were used either as propellants or refrigerants and more than 85% of those CFCs were CFC-11 and CFC-12.

2. Regulatory Milestones

In June of 1974, two researchers (Molina and Rowland) hypothesized that CFCs were depleting the earth's protective ozone shield. Their reported calculations indicated that CFC-11 and -12, developed and valued largely because

of their useful chemical properties, apparently are not destroyed in chemical reactions in the lower atmosphere but diffuse slowly upward into the upper atmosphere. Upon reaching the stratosphere, they photochemically decompose and release chlorine and fluorine atoms, starting a chain of chemical reactions resulting in a net reduction of ozone molecules. The decreased ozone concentration permits more ultraviolet radiation to penetrate the earth, resulting in adverse human health effects such as an increase in the incidence of melanoma and nonmelanoma skin cancer, damage to ecological systems, and climatic perturbations.

It should be noted that not all CFCs are considered to be equally detrimental to the ozone layer. CFC-11, -12, -13, -113, and -114 are considered to be the most potentially detrimental of the commercially produced CFCs because they are thought to reach the ozone-containing stratosphere. Hydrogen-containing CFCs (e.g., CFC-22) are said to be depleted in the lower atmosphere with few or none reaching the stratosphere. CFCs not containing chlorine (e.g., CFC-14) and certain other chlorine-containing CFCs are not implicated. Some of these CFCs which are commercially available are considered to be less hazardous to the ozone layer and, in fact, some have been suggested as possible alternative materials.

Based largely on this study, private and governmental concern over ozone depletion by CFCs began that same year with a November petition to the Consumer Product Safety Commission (CPSC) calling for a ban of CFCs used in aerosols and Congressional hearings on the CFC-ozone depletion hypothesis in December.

From the time that this hypothesis was set forth, a great deal of scientific research was carried out and evaluated periodically. Beginning in 1975, the Council on Environmental Quality (CEQ) and the Federal Council for Science and Technology (FCST) created a joint task force simultaneously with the start of a National Academy of Sciences (NAS) panel to examine the ozone issue.

Both the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) entered the scene in 1976 by announcing their intention to regulate certain aerosol uses of CFCs. After evaluating the findings of two National Aeronautics and Space Administration reports and a second NAS report on the CFC-ozone depletion theory and holding a number of public meetings, EPA and FDA issued regulations in March 1978 banning the nonessential CFC aerosol uses (IRLG, 1980, p. 16). Some CFC-propelled aerosols such as pharmaceutical products, some powders, and limited use pesticides, were ruled as essential and consequently exempted from this ban.

Since the 1978 regulation, little regulatory action has taken place on CFCs. In October 1980, EPA issued an Advance Notice of Proposed Rulemaking (ANPR) for a regulation of non-aerosol CFC uses and received over 2000 comments. Table 5 presents in summary form an abbreviated listing of regulatory milestones.

Table 5. Regulatory Actions and Events Concerning CFCs

June 1974	M.J. Molina and F.S. Rowland of University of California-Irvine published the first scientific report expressing concern over possible significant reductions in stratospheric ozone from CFC releases to the environment (Research showed ozone depletion by CFC-11 and -12).
November 1974	A private environmental organization petitioned the CPSC to ban CFCs in aerosol products.
December 1974	The U.S. House of Representatives Subcommittee on Public Health and Environment held hearings to put on the record the information available concerning the effects of fluorocarbons on the ozone layer.
January 1975	CEQ and FCST jointly created a task force on Inadvertent Modification of the Stratosphere (IMOS). (Its initial charge was to conduct an intensive study of CFC-ozone questions).
January 1975	NAS panel convened to study whether CFCs destroy ozone.
June 1975	CEQ/FCST report was issued on CFCs.
July 1975	CPSC petition was denied on the ground that existing evidence was insufficient to justify regulatory action.

September 1976	NAS issued a report on "Environmental Effects of Chloro-fluoromethane Release" confirming the ozone-depletion theory.
September 1976	EPA, FDA, and CPSC formed interagency regulatory work-group to determine the feasibility of CFC regulation.
November 1976	EPA and FDA issued a "Notice of Intent to Propose Rules" on aerosol uses of CFCs.
November and December 1976	Two public meetings were held in Washington, D.C. to solicit public information on substitutes and alternatives to CFCs.
1977	Amendments adding ozone protection sections were made to the Clean Air Act.
August 1977	NASA report revised the equilibrium ozone depletion estimate upward.
August 1977	Interested members of the public participated in a "legislative-type" hearing before EPA and other agency panelists on the proposed rule.
September 1977	NASA issued a second report on CFCs.
October 1977	FDA labeling order required all cosmetic, drug and food products propelled by CFCs to carry a specific warning label.
October 1977 and February 1978	EPA and FDA held two public meetings to obtain information from industry about non-aerosol uses of CFCs, particularly CFC refrigerants.
December 1977	NAS report evaluated all the evidence and updated information on the CFC-ozone-depletion theory and concluded that CFC-11 and CFC-12 releases posed the major threat to the ozone layer.
March 1978	EPA and FDA issued CFC aerosol regulations banning nonessential aerosol use as of October 15 and December 15, 1978 for CFC-11, CFC-12, CFC-114, CFC-115.
November 1978	EPA issued clarification statement on definition of "aerosol propellant."
1979	NASA sponsored an ozone workshop.
1980	NAS report revised CFC-ozone depletion models and effects, cautioned against continuation of current CFC

consumption levels, and detailed the extent of refrigerant emissions.

October 1980

EPA issued an Advance Notice of Proposed Rulemaking (ANPR) for regulation of non-aerosol CFC uses.

In summary and for purposes of the following analysis, CFCs have been subject to two pre-regulatory periods, the first focusing on CFC aerosol applications and the second on non-aerosol applications. The first began in 1974 with the original scientific study on CFC-ozone depletion and culminated four years later with the issuance of the CFC aerosol use regulations. The second pre-regulatory period can be thought of as beginning in 1977-78 at the time of the EPA/FDA interest in refrigerants and non-aerosol CFC applications and continuing to the present.

E. REGULATORY ANALYSIS

Based on the preceding summary of consumption and use characteristics, environmental concerns, and regulatory actions affecting CFCs, it is apparent that two members of the CFC family in particular, CFC-11 and -12, were viewed to pose the greatest potential hazard because of their ubiquitousness in all principal use categories reviewed. In addition, the first regulatory actions designed to limit atmospheric CFC emissions focused on aerosols, at that time the largest consumption category of CFC-11 and -12. However, these two CFCs are also consumed in other non-aerosol applications which, before regulatory actions accounted for less than 50% of total consumption, but now account for all but 2% (Table 1).

Therefore, this section will examine trends in the production and use of CFC-11 and -12 in both aerosol and non-aerosol applications to assess the extent to which designation of CFCs (CFC-11 and -12 in particular) as suspect toxic hazards affected their production and use.

1. Aerosol Applications

Table 6 and Figure 1 present a profile of total CFC domestic consumption by principal use (based on Table 6 and figure 1).

Table 6. Domestic Consumption of Chlorofluorocarbons (mill. lbs.)

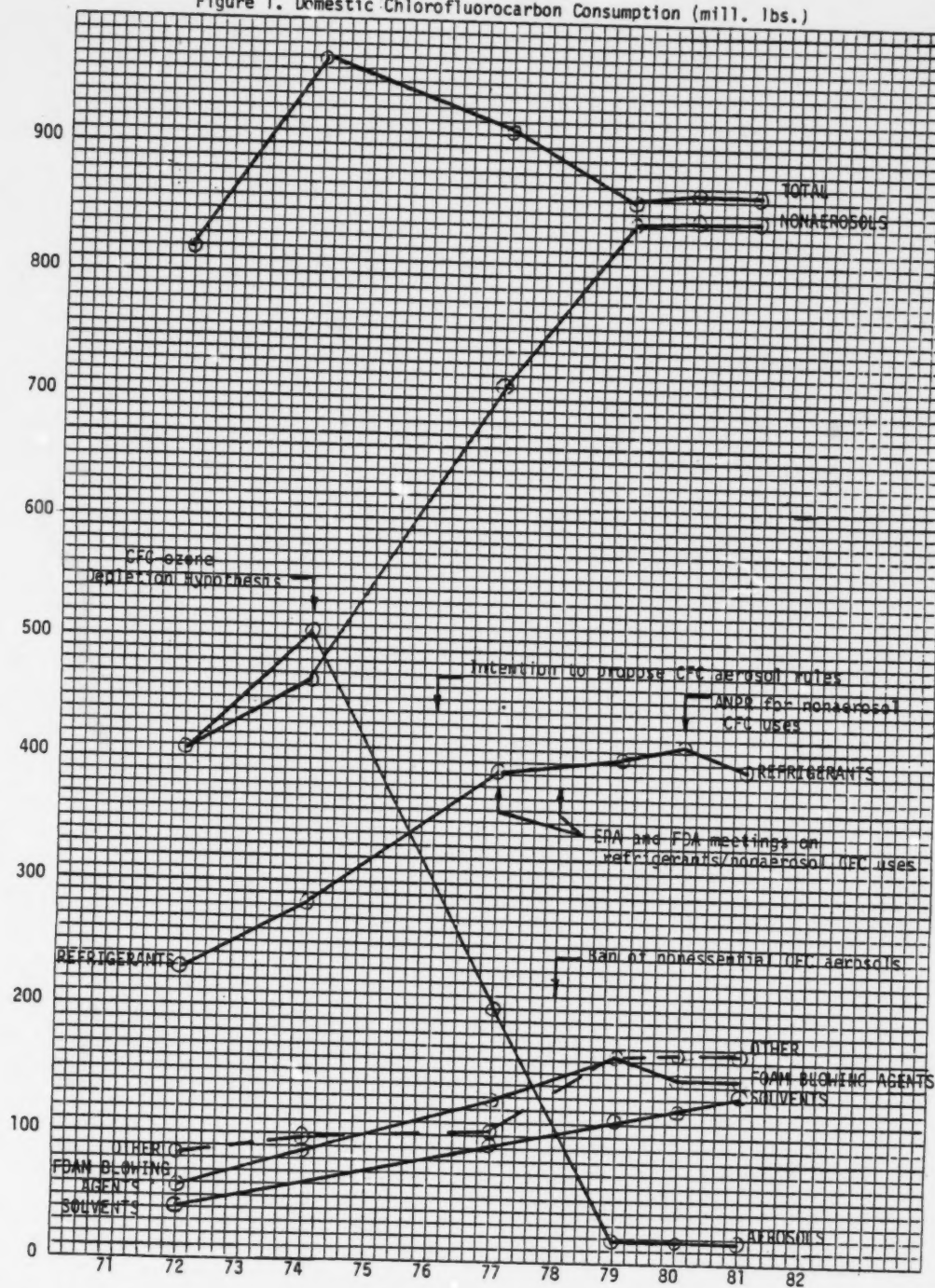
<u>Year</u>	<u>Total Consumption</u>	<u>Aerosols</u>	<u>Refrigerants</u>	<u>Foam-Blowing Agents</u>	<u>Solvents</u>	<u>Other</u>	<u>Total Non-aerosol</u>
1972	819	409.5	229.3	57.3	41	81.9	409.5
1974	969	503.9	281.0	87.2	NA	96.9	465.1
1977	912	200.6	392.2	127.7	91.2	100.3	711.4
1979	859	17.2	403.7	163.2	111.7	163.2	841.8
1980	864	17.3	414.7	146.9	121.0	164.2	846.7
1981	862	17.2	396.5	146.5	137.9	163.8	844.8

Sources: Tables 1 and 3.

Although the time series in this table are discontinuous for some years, it is readily evident from these consumption trends that aerosol applications have decreased dramatically since 1974. This is in striking contrast to increasing consumption of CFCs in non-aerosol applications for the same time period. As aerosol applications decreased 97%, aggregate non-aerosol applications exhibited an 81% gain in consumption, resulting in a net decline in total CFC consumption of 11% between 1974 and 1979.

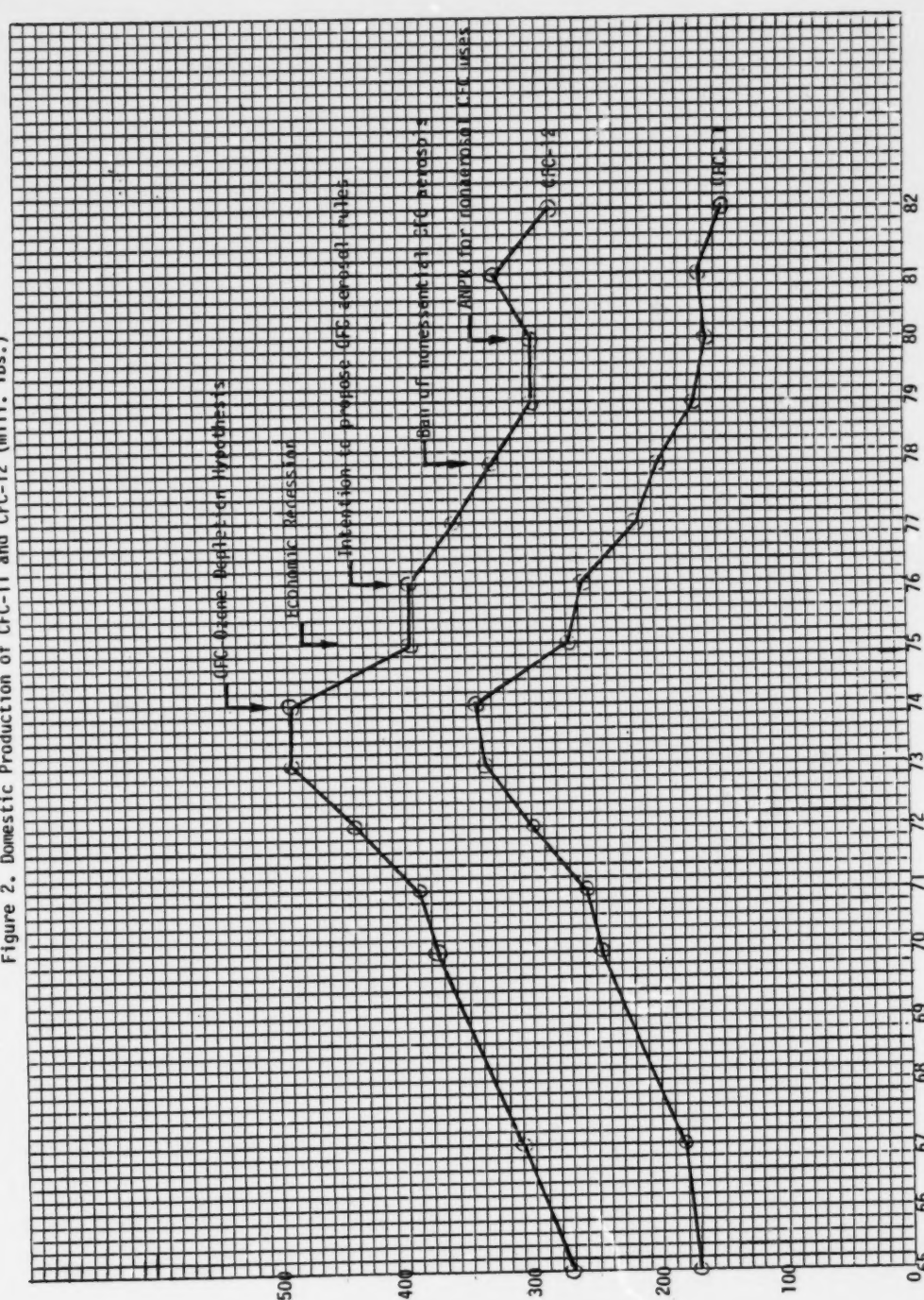
Because CFC-11 and -12 comprised over 90% of all CFCs used in aerosol applications, it is useful to examine their individual production trends, as illustrated in Figure 2. The time series data for CFC-11 and -12 production are continuous for the years of interest and confirm that production declines did indeed begin in 1975. These declines in production of CFC-11 and -12 were 51% and 60%, respectively, less than the 97% decline exhibited in aerosol consumption of CFCs. This difference can be explained by the fact that both CFCs are also consumed in non-aerosol applications, particularly refrigerants and foams, which exhibited increases in CFC consumption of 44% and 97% from 1974 to 1979.

Figure 1. Domestic Chlorofluorocarbon Consumption (mill. lbs.)



Source: Table 6.

Figure 2. Domestic Production of CFC-11 and CFC-12 (mill. lbs.)



Source: Table 3.

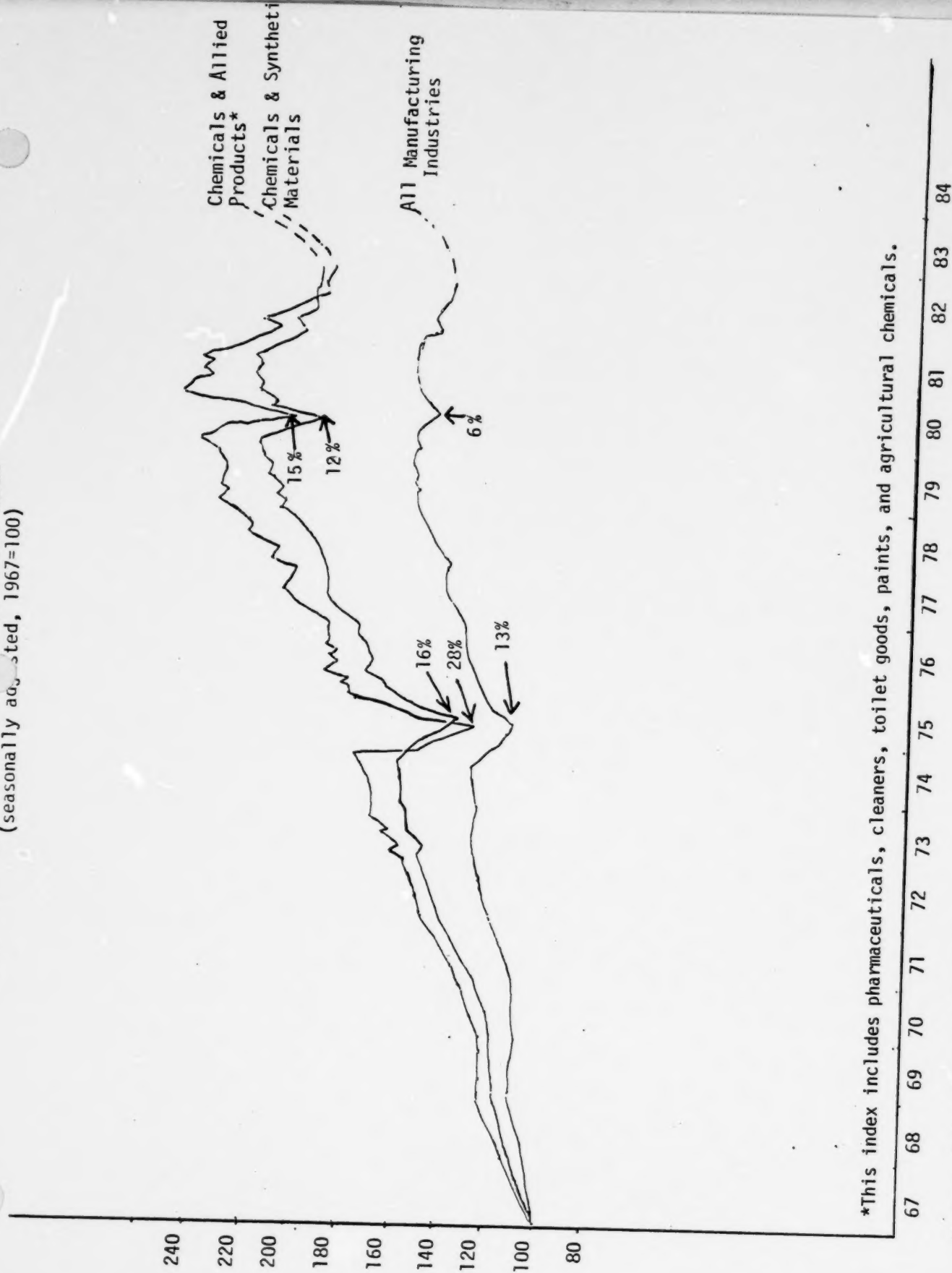
The hypothesis was tested that the general economic recession of 1975 could account for the production decline beginning in that year. However, the declines in CFC-11 and -12 production between 1974 and 1975 were 21% and 19%, respectively, substantially greater than the 16% decline in the Chemicals and Allied Products production index for that year as shown in Figure 3. This suggests that other factors in addition to general economic activity accounted for the decline. In addition, CFC production continued its decline in 1976, and the index rebounded in that year.

The hypothesis was also tested that the relative price of substitutes, i.e., a consumer switch to aerosols containing less-costly propellants, could offer an economic explanation for the decline in CFC propellant aerosols. Alternative propellants include hydrocarbons (mainly butane, propane, and isobutane) and carbon dioxide (CO_2). Hydrocarbons are less expensive than CFCs but are more toxic, flammable, potentially explosive, and usually have characteristic odors. Carbon dioxide is also much less expensive than CFCs, but is limited by the fact that it can react with water in aerosol products to produce carbonic acid which corrodes the inside of canisters. As propellants, neither hydrocarbons or CO_2 deliver as fine a spray as CFCs-11 and -12. (Chemical Week, 119:17, 9/29/76).

Thus, both the technical aspects and marketing qualities of CFCs used as propellant outweighed relative price advantages of alternatives. The higher costs of these compounds compared with prices of available substitute chemicals had been accepted by the public in registering its preferences because they posed lower immediate health risks (before the 1974 scientific findings) and afforded greater convenience in certain applications.

There is a consensus that it was the regulatory actions of the mid-1970s and, in particular, in the 1978 ban on nonessential CFC aerosol uses, that accounted for these observed consumption changes. However, a number of different types of regulatory actions took place during this period and as evidenced by Figures 1 and 2, the decline in aerosol consumption for aerosol uses began in 1974, well before the ban. It is interesting to note that the major

Figure 3. CHEMICAL & INDUSTRIAL PRODUCTION INDEX
(seasonally adjusted, 1967=100)



*This index includes pharmaceuticals, cleaners, toilet goods, paints, and agricultural chemicals.

Source: Federal Reserve Board

consumption changes correlate closely with the 1974 publication of the first scientific report on the CFC-ozone depletion hypothesis and the petition calling for a CFC aerosol use ban, i.e., the start of the CFC pre-regulatory suspect hazard scrutiny period. (Figure 1 also shows that CFC aerosol consumption never actually reached zero after the ban but leveled-off in 1979 because of certain uses that were exempt from the 1978 ban.)

Based on the relation between milestone suspect hazard events and consumption/production changes in Figures 1 and 2, CFC aerosol applications appear to provide an exemplary case of manufacturer behavioral modifications resulting from pre-regulatory suspect hazard scrutiny. In light of growing scientific evidence and reports on the adverse effects of CFC emissions (CFC-11 and -12 in particular), swelling Government concern and interest, consumer-oriented action in terms of a CPSC ban petition and possible reduced consumer demand for CFC propellant aerosols, CFC manufacturers voluntarily reduced production of both CFC-11 and -12 well before issuance of the actual 1978 regulations which mandated a phase-out of these CFCs in non-essential aerosol uses.

The sources that gave rise to the impetus for CFC manufacturers to decrease CFC-11 and -12 production in the face of growing concerns over these potentially hazardous substances is not fully known. In conjunction with regulatory actions, there were numerous articles in the popular press referring to the ozone problem and to the effects of CFCs on the depletion of the ozone layer. It appears that shifts in consumer preference patterns toward non-CFC propellant aerosols or other aerosol alternatives as a result of these media articles operated in concert with other specific suspect hazard regulatory influences on CFC manufacturers to impel them to reduce production.

For the aerosol industry, hydrocarbons were the obvious benefactors of the CFC ban. Hydrocarbon propellants at the time of the ban in 1978 were already being used in 50% of aerosol applications, with carbon dioxide propellants also increasing in use. It is reported (Product Marketing, Dec. 1979, p. 26) that as a result of growing environmental concerns, consumers started to switch to CFC

propellant substitutes quickly, especially in the personal care area. One metal canister maker claimed a 26% loss of its aerosols sales during the first half of 1975 (Modern Packaging, 51:23-8, Feb. 1978). Consumer purchases of total aerosol products dropped 36% before the ban and would have dropped further if not for a large increase in purchases of hydrocarbon propelled aerosols. Consumer purchases of alternatives such as pump applicators, roll-ons, sticks, etc., also increased, suggesting further that changing consumer demand might have been the key factor in reducing CFC aerosol production.

Consumer awareness was further increased by some degree of aerosol marketer panic and a mini war of words in advertising as early as 1975. Firms offering CFC aerosol product substitutes (e.g., S.C. Johnson) placed full-page advertisements in large city newspapers boasting that their products contained no CFCs. Many of them used product labels which read as follows: "Contains no fluorocarbons claimed to harm the ozone layer." Marketers also used television advertisements for their anti-aerosol campaign during 1976 and 1977. On the other hand, firms with considerable stakes in CFCs (e.g., Du Pont, manufacturer of Freon[®]) indicated in their own advertisements that they were funding extensive research and that the ozone depletion theory lacked substantiating evidence. They generally blasted the regulatory approach to CFCs (Drug and Cosmetic Industry, August 1975). Announcement of FDA labeling order (October 1977) and the forthcoming ban came amidst a growing body of evidence that a generally bad press had already precipitated a consumer switch to non-aerosols (Drug and Cosmetic Industry, 120:28-33, June 1977).

2. Non-aerosol Applications

Consumption of CFCs for non-aerosol applications increased substantially during the 1974-78 pre-regulatory period. Of the total 81% increase, refrigerants increased 44%, solvents 86%, foam-blowing agents 87%, and other non-aerosol uses 68%. As with aerosol products, consumption in all categories of non-aerosol applications leveled-off after 1979. Because these use categories were not subject to the same regulatory threat and press attention as CFC-

containing aerosols, CFC consumption exhibited increases in these non-regulated uses, thereby offsetting the detrimental effect of the aerosol-related pre-regulatory events on CFC producers. An interesting case in point is CFC refrigerants. Adjustment of CFC consumption for use as refrigerants, as shown in Figure 4, in terms of either total hours worked in the refrigeration and air condition equipment industry (curve A) or annual sales of refrigeration condensing units and room and vehicle air conditioning units (curve B) shows that CFC refrigerant consumption increased at a greater rate than refrigeration/air conditioning industry growth. The causes of such CFC consumption growth relative to total industry growth are not clear. A ban placed on a major use of a chemical could quite possibly result in a price decrease resulting from a decline in demand. However, the price trends for both CFC-11 and -12, as shown in Figure 5, indicate that no price reductions occurred. On the contrary, major price increases were observed during the beginning of the pre-regulatory suspect hazard period (1974) and at the time of the 1978 ban. However, these two periods coincided with general price inflation resulting from oil supply disruptions in 1973 and 1979, so that any regulatory impact on price is difficult to assess.

For refrigeration, it has been reported (EPA, 1976, p. 9) that few truly feasible chemical substitutes for R-11 and R-12 are available for use in residential and commercial mechanical vapor compression refrigeration and air conditioning systems. While ammonia, sulfur dioxide, hydrocarbons, and chlorinated hydrocarbons are technically feasible substitutes, problems such as toxicity, flammability, materials incompatibility, and the necessity for systems redesign appear to preclude any substantial conversion to the use of such materials as refrigerants (EPA, 1976, pp. 8, 9).

For foam-blowing applications, it has also been reported (EPA, 1976, pp. 10, 11) that CFCs are considered essential to achieve low thermal conductivity required for insulating foams, although certain other halogenated compounds are known to offer comparably low thermal conductivity. On the other hand, CFCs account for a minor share (5%) of solvent use (degreasing and dry cleaning) and are used mostly as (azeotrope) mixtures with other cleaning agents. It appears

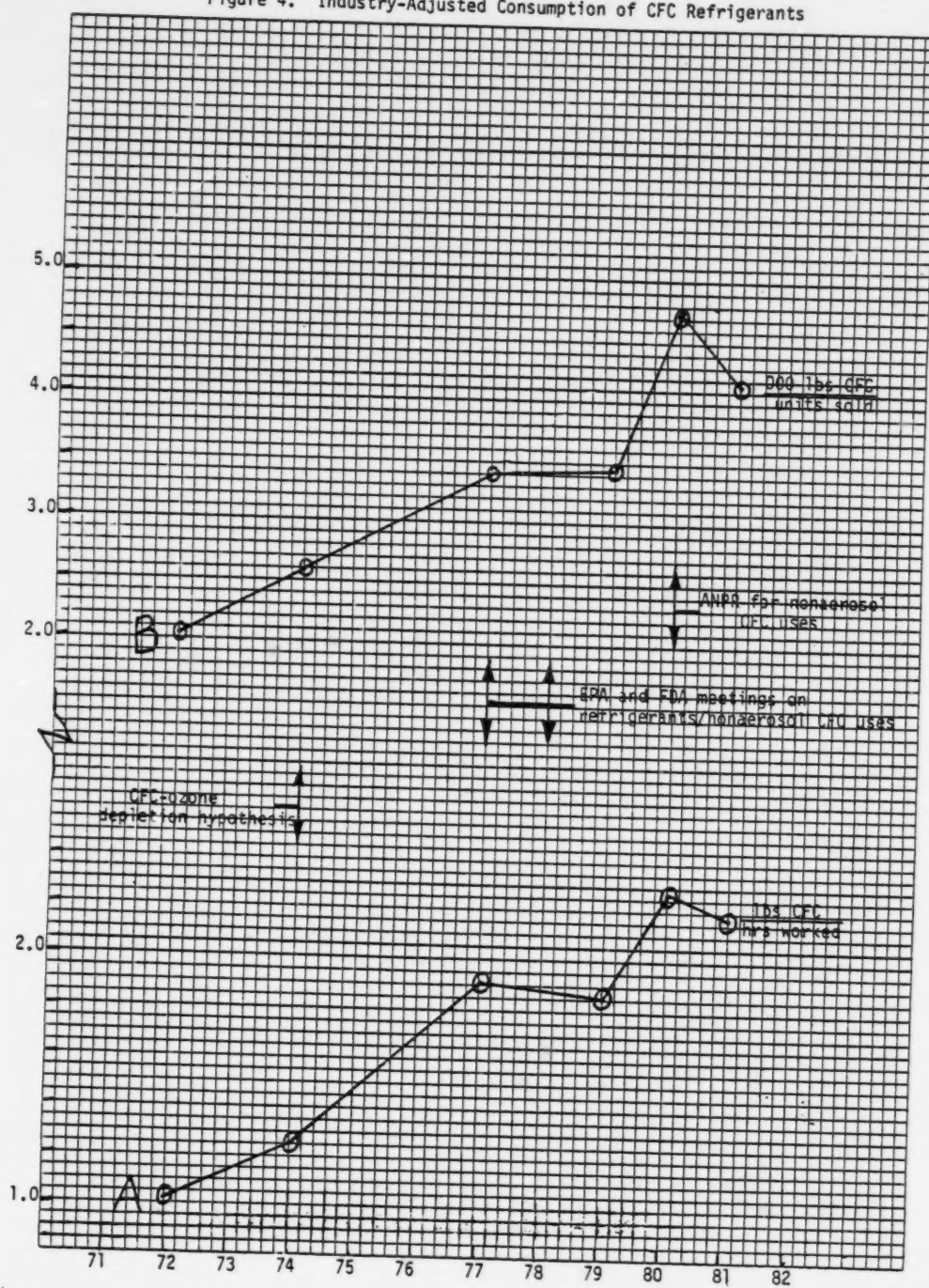
that price is a minor factor in this use category: in 1975, CFC mixtures were over 2.5 times as expensive as possible chlorocarbon (e.g., perchloroethylene, trichloroethylene) and alkaline cleaner substitutes.

Thus, relative price and production relationships of CFC substitutes in non-aerosol applications, make it appear that CFCs may impart specific properties or meet specifications that no other known and currently-available substitutes can duplicate. Such a situation is in contrast with aerosol applications for which, with the exception of a few cases of essential use alternative methods of delivering aerosol products were available and already on the market. It would seem that non-aerosol CFC consumption, unrestricted by regulatory actions and unencumbered by unfavorable publicity or media attention, simply expanded with general growth in these major non-aerosol uses.

The regulatory events specific to non-aerosol CFC applications which might potentially affect CFC production and use were the October 1977 and February 1978 EPA/FDA public meetings to gather information about refrigerants and non-aerosol CFC uses and the October 1980 ANPR issued by EPA. As mentioned above, non-aerosol uses increased by 68% from 1974-1978. However, it is interesting to note that the growth in refrigerants between 1977 and 1979 was a much smaller 3% compared with an average of 38% for the other three non-aerosol use categories. This suggests that regulatory actions of 1977-78 might have affected refrigerants in a relative sense more by dampening their growth as compared with other non-aerosol CFC use categories. This suggestion is reinforced by the fact that CFC refrigerant use increases also slowed down relative to consumption in the refrigeration/air conditioning industry itself in the years 1977-78, as shown in Figure 4.

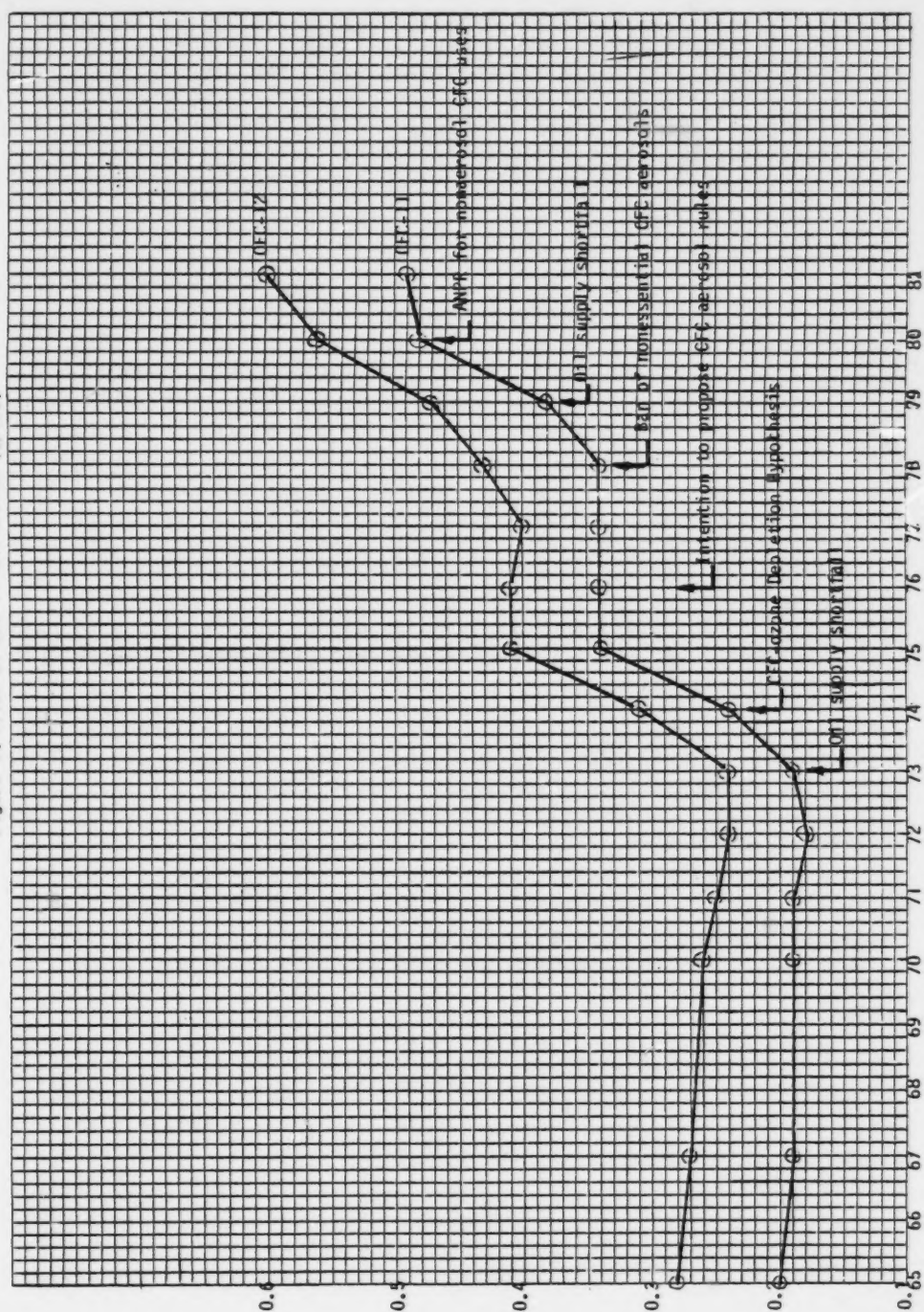
A review of product marketing literature confirms that EPA's concerns with CFC emissions from refrigerants arose out of the fact that 100% of CFCs used as refrigerants are eventually emitted to the atmosphere and that as aerosol CFC uses abruptly phased out, refrigerants became the major demand CFC category, growing from 29% of total CFC demand in 1974 to 47% in 1979. The

Figure 4. Industry-Adjusted Consumption of CFC Refrigerants



Source: Table 6; Predicasts Basebook, pp. 564-6.

Figure 5. Price of CFC-11 and CFC-12 (\$/lb.)



Source: Predicasts Basebook, p. 377.

purpose of the 1977 and 1978 public meetings as stated by EPA were to deal with refrigerants and "to get at the nonessential uses" (Chemical and Engineering News, May 1977). Therefore, it is plausible that refrigerant producers reduced production of F-11 and -12 (F-22 is also used as a refrigerant but is considered to be less hazardous to the atmosphere) and began offering substitute refrigerants on the market in anticipation of and preparation for future regulations.

It is also interesting to note that consumption of CFCs as refrigerants declined 4% in 1981 after EPA's ANPR for non-aerosol CFC uses was issued in 1980. However, without more recent data it is not possible to fully estimate the impact of this regulatory action on non-aerosol CFC consumption.

F. SUMMARY

In summary, CFCs have been subject to a rather short regulatory history beginning with publication of scientific evidence on the CFC-ozone depletion hypothesis in 1974 followed by two pre-regulatory periods. The first pre-regulatory period focused on CFC aerosol applications, ending upon issuance of the 1978 ban and the second, beginning in 1977-78 and continuing to the present, focused on refrigerants and other non-aerosol CFC uses.

To assess the impact of these pre-regulatory and regulatory events, trends in the production and consumption of CFCs (CFC-11 and -12 in particular) were examined together with supply factors for both aerosol and non-aerosol CFC applications.

For aerosol applications, it was found that the decline in production of CFC-11 and -12 was associated with the start of the pre-regulatory suspect hazard period, suggesting that voluntary actions were taken on the part of CFC producers to reduce the potential hazard associated with CFCs, i.e., their use in aerosols. Changing consumer demand resulting from awareness of the ozone problem was a significant factor contributing to the change in producer behavior.

Non-aerosol applications were subject to a lesser degree of regulatory emphasis until 1977-78, and consumption of CFCs increased in this category. This increase (81%) largely offset the large aerosol use decline (97%) so that net CFC consumption was reduced only slightly until 1979. Of all non-aerosol applications, consumption of CFCs for use as refrigerants during this period grew most slowly (44%), a result which is consistent with regulatory focus on this application starting in 1977.

SECTION II.6

REGULATORY IMPACT ANALYSIS FOR CHROMIUM COMPOUNDS

The purpose of this summary is to report on the market impact of designating chromium (VI) compounds as suspect toxic hazards. An estimate of such impact depends on careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. INTRODUCTION

Chromium is one of modern industry's most versatile elements. It has a wide range of uses in the metallurgical, chemical, and refractory industries. In metallic form, chromium is used as a constituent in stainless and alloy steels, heat- and corrosion-resistant materials, and refractories for metallurgical furnaces. In the form of chemical compounds, chromium is used in pigments, metal plating, leather tanning, and other chemical uses.

Chromium as a metal is biologically inert and does not produce toxic or other harmful effects in man or laboratory animals. Compounded, it has oxidation states ranging from Cr^{-2} to Cr^{+6} with only two forms — trivalent and hexavalent — found in nature.* Compounds of chromium in the trivalent state have no established toxicity. The health problems associated with chromium are related to hexavalent chromium compounds which are irritant, corrosive, and reported to be carcinogenic, and may be absorbed by ingestion, through the skin, and by inhalation. Chromium (VI) compounds commonly manufactured include sodium bichromate ($\text{Na}_2\text{Cr}_2\text{O}_7$), sodium chromate (Na_2CrO_4), potassium bichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), potassium chromate (K_2CrO_4), ammonium bichromate ($(\text{NH}_4)_2\text{Cr}_2\text{O}_7$), and chromium (VI) oxide (CrO_3), commonly known as chromic acid.

* The "oxidation state," "valent state," or "valency" of a chemical element specifies the number of electrons present in its outer-most electronic shell, i.e., the least energetic electrons farthest from the atom's nucleus. The presence or absence of these electrons determines the chemical reactivity of the element.

Only those aspects of consumption and use characteristics, supply factors, and regulatory history associated with chromium (VI) compounds will be examined in this analysis.

B. CONSUMPTION AND USE CHARACTERISTICS

Chromium compounds (Cr(VI)) are essential to many industries. Three principal use categories currently account for about 70% of Cr(VI) consumption: pigments, metal treatment, and leather tanning. Table 1 shows the principal use profile for Cr(VI).

Table 1. Principal Uses and Consumption of Chromium (VI) Compounds

<u>Use</u>	<u>Percent of Total</u>				
	<u>1970</u>	<u>1972</u>	<u>1975</u>	<u>1978</u>	<u>1981</u>
Pigments	31.1	33.3	26.0	26.2	26.3
Metal Treatment	24.2	23.6	24.9	25.3	25.0
Leather Tanning	15.0	14.0	18.3	17.7	17.8
Corrosion Control	7.4	8.2	6.7	7.8	7.6
Wood Preservatives	6.5	6.5	7.2	7.4	7.4
Drilling Muds	4.4	3.7	3.8	5.0	5.1
Other	11.4	10.7	13.1	10.6	10.8

Source: Derived from Chemical Marketing Reporter.

Chromium pigments represent the largest use of chromium in the chemical industry. Sodium bichromate (the primary base material for manufacture of chromium chemicals) is used to manufacture chrome green, chrome oxide green, chrome yellow, molybdenum orange, and zinc chromate pigments. The primary applications for chrome pigments are in plastics and printing inks. Chrome pigments are also used in yellow paints for marking lines on roads; in industrial surface coatings for automobiles, appliances, tractors, and other heavy equipment; in corrosion-inhibiting pigments used primarily as paint primers for metals; in camouflage paints (the infrared reflectance of chromic oxide resembles green foliage); and in coloring synthetic gem stones.

The most important use of Cr(VI) in metal treatment is in the production of chromic acid for use in chromium plating. Chromium is applied to other metals by electrolysis in a solution of chromic acid. Decorative chromium plating is usually deposited over a nonferrous base such as copper or nickel. This type of plating is used for automobile trim, appliances, plumbing fixtures, and other consumer products. For industrial purposes, heavier coats of chromium are applied directly to metals such as iron, steel, and aluminum. This technique, which is known as hard plating, reduces friction and prolongs the life of bearings, molds, and automotive parts such as cylinder liners and piston rings. Chromic acid is used to anodize aluminum and aluminum alloys and to produce chemical conversion coatings on zinc, cadmium, steels, and other metals. Treatment with chromic acid increases both corrosion resistance and paint adhesion. Chromic acid is also used in formulations for metal pickling, cleaning, and etching.

Although Cr(VI) compounds are the most important commercially, the bulk of the applications in the tanning industry depend on the ability of Cr(III) to form stable complexes with proteins in the hide substance. All Cr(VI) (bichromate) used in tannery operations is reduced in a solution of sulfuric acid and an organic compound (usually sucrose) to the trivalent state before reacting with hides to form leather. The chrome tanning of leather is one step in a complicated series of operations leading from the raw hide to the finished product. Chrome tanning is the most important tannage for all hides except heavy cattle hides, which are usually vegetable-tanned. Chrome tanning processes are relatively short and simple compared with other methods and yield a leather that is both heat- and wear-resistant.

Sodium bichromate and chromate are also used to inhibit metal corrosion in circulating water systems such as air conditioners, cooling towers, boilers, and internal combustion engines. Because of their superior effectiveness at high temperatures, chromium chemicals are the preferred corrosion inhibitor for circulating systems of chemical plants and oil refineries.

The production of wood preservatives is considered to be the fastest growing market for chromium-containing chemicals. Such chemicals not only reduce corrosion but also act as binders to prevent other preservatives from

leaching from the wood. As a result, water soluble fungicides and fire retardants are often used in conjunction with chromium-containing preservatives such as chromated copper arsenate (CCA). Because of the fact that arsenic is a constituent with chromium in wood preservatives and has been separately regulated as a suspect toxic hazard, the wood preservative use category will not be examined as part of the regulatory impact assessment of chromium compounds. (The impact of suspect hazard and regulatory designation on wood preservatives, and in particular CCA, is presented in the preceding report on Arsenic.)

Since 1941, chromium chemicals have been used in drilling muds to prevent fatigue corrosion cracking of drill strings. Other minor uses of Cr(VI) compounds include catalysts, mordant dyes for textiles, pharmaceuticals, high fidelity chromium dioxide magnetic tapes, and other miscellaneous applications.

C. SUPPLY FACTORS

Although chromium is found in various minerals, chromite is the sole source of chromium used commercially. The mineral chromite consists of varying percentages of chromium, iron, aluminum, and magnesium oxides. It is mined by both conventional surface and underground methods.

With the exception of small amounts of chromite produced in California in 1976, no chromite has been mined in the United States since 1961. The domestic chromite-consuming industries are dependent on foreign supply except for material purchased from government stockpile excesses. The leading producers of chromite—the USSR, the Republic of South Africa, Turkey, the Philippines, and Zimbabwe—are also the principal suppliers of chromium to the United States. Some chromite from sale of Government stockpile excesses moved into domestic trade flow in recent years, but the material was purchased at discount. Because domestic ore tends to be low grade and deposits usually small, such ore is not competitive with ore from other countries.

Historically, world political problems have brought supply disruptions for chromite. Because of the Korean conflict, the Soviet Union in 1950 embargoed exports of chromite to the United States until 1960. Imports of Rhodesian chromium were embargoed by the United States from early 1966 to 1972. More

recently, no supply disruptions have been reported. Table 2 provides data on imports, consumption, and price of chromite.

Table 2. U.S. Salient Statistics for Chromite

Year	Average Price (\$/lb) ¹	Net weight Cr ₂ O ₃ (000 metric tons)			
		Domestic Supply (Imports)	Total Consumption ²	Consumption for Chemicals	
				Actual	% of Total
1965	54	621	643	89	13.8
1966	53	763	590	79	13.4
1967	56	515	559	73	13.1
1968	53	453	542	82	15.1
1969	58	459	582	86	14.8
1970	72	587	575	87	15.1
1971	79	535	450	74	16.4
1972	81	453	467	78	16.7
1973	74	374	569	84	14.8
1974	87	436	582	102	17.5
1975	159	507	340	68	20.0
1976	192	484	383	84	21.9
1977	190	488	371	87	23.4
1978	184	376	366	98	26.8
1979	130	377	441	99	22.4
1980	135	372	345	99	28.7
1981	NA	334	305	97	31.8

¹ Based on value of chromium in imported chromite.

² Difference between imports and consumption is accounted for by changes in industry stocks.

Source: US BOM, Mineral Facts and Problems, p. 176.
 US BOM, Minerals Yearbook, 1981.
 US BOM, Mineral Commodity Summaries, 1982, p. 32.

Sodium bichromate is the major chemical product derived from chromite and is used primarily in the production of chromic acid (principally used for metal treating), chromium pigments, and in leather tanning. Three chemical firms at three locations (Allied Chemical - Md., Diamond Shamrock - N.C., and Harrisons and Crossfield (U.K.) - Tex.) produced the basic chromium chemical, sodium bichromate, from which other chromium chemicals have been derived. Producers of Cr(VI) chemicals have generally operated at 80-90 percent capacity. This same

excess capacity appears to have characterized this industry. (US BOM Mineral Facts and Problems, p. 169.)

D. REGULATORY HISTORY

1. Environmental/Human Health Concerns

Knowledge of the harmful effects of hexavalent chromium (Cr(VI)) is derived almost entirely from occupational exposures, where the effects have been on the respiratory system and skin. What were probably the first cases of occupational injury (skin ulcers) due to exposure to chromium (VI) compounds (during production of potassium bichromate) were reported in 1827 in Scotland and in 1869 in France. Other cases of worker injury (pulmonary carcinoma) in the manufacture of chromium (VI) compounds were reported in 1930, 1935, 1936, 1938, and 1943 (Germany). It was not until 1948 that an excessive incidence of lung cancer was reported among workers in the United States chromate industry. The U.S. Public Health Service conducted a health study on workers in chromate-producing plants in 1953 and determined that the prevalence of adverse health effects appeared to increase with time worked in the chromate industry.

Workers in industries which consumed chromate (VI) compounds also exhibited adverse health effects. In 1916 and 1930, skin ulcers were reported among workers in the chrome leather tanning industry. However, because all chromium used in the actual tanning process is in the non-toxic trivalent (Cr^{+3}) state, it may not clear whether Cr(VI) exposure was the problem. Potential exposure to Cr(VI) could only result during the preparation (adding bichromate to sulfuric acid) of the tanning solution. There is no Cr(VI) present in tannery wastewaters.

Workers employed in chromium plating operations were found to be exposed to chromic acid mists emanating from plating tanks. Studies in 1928, 1930, 1953, 1965, and 1972-74 reported airborne Cr(VI) concentrations and instances of skin ulcers and perforated or ulcerated nasal septa among the workers.

Adverse health effects from exposure to Cr(VI) pigments during production and use (e.g. primer paints) were documented in 1943, 1944, 1962, 1963, and

1975 (British). Less frequent reports on Cr(VI) poisoning were published for exposure to Cr(VI)-containing cement dust (1952), radiator fluid (1951), lithographics (1931), and blueprints (1925). It is also reported that industrial workers dealing with fungicides, wood preservatives, and corrosion inhibitors were found to have been exposed to Cr(VI).

2. Regulatory Milestones

The first standard in the United States specifically applicable to Cr(VI) was published by the American Standards Association (now the American National Standards Institute) in 1943. This standard, based largely on the 1928 chrome-plating study, established allowable airborne concentrations for Cr(VI) compounds of 1 mg per 10 cubic meters of air (TWA), for worker exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) also published a threshold limit value (TLV) soon after ANSI (1947) of 0.1 mg/m^3 . In 1971, the ANSI reaffirmed the 1943 standard, thus updating it, but leaving it unchanged. Then in 1973, the ANSI recommended a standard of 0.3 mg/m^3 Cr(VI) ceiling with the 0.1 mg/m^3 TWA unchanged.

In 1971, the first federal standard of 0.1 mg/m^3 TWA was adopted under the Occupational Safety and Health Act, based on the ACGIH and ANSI values. The second federal action on chromium was the NIOSH recommendation for a new standard in 1975 resulting from 1973 investigations of chromium plating plants. This action followed the 1974 release of an extensive study by the National Academy of Sciences on the biologic and health effects of chromium. NIOSH separated chromium (VI) compounds into two categories with 0.05 mg/m^3 TWA for what NIOSH considered as "noncarcinogenic chromium (VI)" (i.e., monochromates and bichromates) and a 0.1 mg/m^3 TWA for "carcinogenic chromium (VI)" (all other chromium (VI) compounds).

EPA regulated chromium (VI) compounds in 1976 under the Clean Water Act, specifying both a drinking water limit of 0.05 mg per liter and temporary waste water effluent limits for chromium discharge from electroplating facilities.

In 1978, OSHA proposed to revise its 1971 Cr(VI) exposure standard based on the NIOSH recommendations of 1975 but did not publish a proposed new standard. Since 1978, a number of federal regulatory actions have taken place,

focusing primarily on chromium discharge from electroplating operations. Table 3 provides a summary of the establishment of standards and regulations for chromium (VI) compounds. Also included in Table 3 are two lead-related events (1975, 1978) which have possible relevance (to be explained below) to the estimation of regulatory impact on chromium pigments.

Table 3. Establishment of Standards and Regulations for Chromium (VI) Compounds

1827	First report of occupational injury due to Cr(VI) exposure
1943	ANSI published worker exposure limit standard to airborne Cr(VI) (0.1 mg/m^3 TWA).
1947	ACGIH published worker exposure limit to Cr(VI) (0.1 mg/m^3 TWA).
1948	Evidence of Cr(VI) carcinogenicity found in the United States.
1971	ANSI reaffirmed 1943 standard.
1971	OSHA worker exposure standard of 0.1 mg/m^3 TWA issued for Cr(VI).
1973	ANSI recommended 0.3 mg/m^3 ceiling for Cr(VI) exposure.
1973	NIOSH published two investigations of separate chromium plating plants, measuring airborne Cr(VI) concentrations and worker health.
1974	NAS published its critical evaluation of the literature (up to 1972) on the biological and health effects of chromium.
1975	NIOSH published a Criteria Document recommending two new worker exposure standards for "noncarcinogenic" (0.05 mg/m^3 TWA) and "carcinogenic" (0.01 mg/m^3 TWA) Cr(VI) compounds based on its 1973 studies.
1975	OSHA proposed a new lead standard (relevant to Cr(VI) because 80% of all chromium pigments contain lead).
1976	EPA established temporary waste water effluent discharge standards for chromium from electroplating operations and a drinking water limit of 0.05 mg per liter under the Clear Water Act.
1978	OSHA proposed to revise its 1971 occupational exposure standard for Cr(VI) but did not publish a proposed new standards.
1978	OSHA finalized a new lead standard (see chromium pigments).

- Dec. 1978 IRLG task force was established for chromates but stated that "At present, no agency is highly active in regulating chromates."
- Oct. 1980 EPA proposed an amendment to the May 1980 hazardous waste rules to restrict regulation to hexavalent chromium rather than all valences.
- 1979 EPA published final effluent guidelines for the electroplating and rubber manufacturing point source categories.
- Oct. 1979 EPA published draft water quality criteria for chromium as one of 65 chemicals for which it was under court order to publish such criteria.
- Sept. 1979 Final EPA rules establishing specific limits on the amount of chromium discharge were published for the electroplating industry category.
- 1980 EPA proposed waste water regulations for the manufacture of inorganic chemicals.
- April 1981 A tax levied on chromite under the Superfund Act of 1980 to help finance the clean-up of hazardous chemical spills and waste sites. Producers and importers of chromite were required to pay a tax of \$1.52 per short ton (\$1.68/m.t.) of ore.
- 1981 The CPSC focused on chromium as part of a project to determine the potential for consumer exposure to toxic heavy metals released from consumer products.
- June 1982 EPA finalized regulations applying to chrome pigments and sodium bichromate intended to mandate the change from best practicable technology (BPT) to best available technology (BAT), but deemed the change too costly for the chrome chemicals industries to bear.
- Aug. 1982 EPA proposed new standards for metal finishing industries (electroplating) requiring these point sources to reduce the limit on the chromium content of their effluents.

From this regulatory overview, Cr(VI) compounds have been subject to what can be considered as three regulatory periods in the United States. The first two periods focused on all occupations and work places where there was exposure to Cr(VI) compounds. The first period began with the first U.S. worker exposure limit to airborne Cr(VI) in 1943 and ended in 1971 with the first federal (OSHA) standard for airborne Cr(VI). The second period started in 1975 with NIOSH

recommendations for reducing worker exposure limits to Cr(VI) compounds, and continued to the present with no new proposed or final standard yet issued. The third regulatory period can be thought of as focusing on chromium plating operations. It started in 1973 with chromium plating industry studies by NIOSH (earlier reports had been published on the subject but most were foreign) and also has continued to the present, as evidenced by the August 1982 EPA action proposing new plating standards.

E. ANALYSIS OF REGULATORY IMPACT

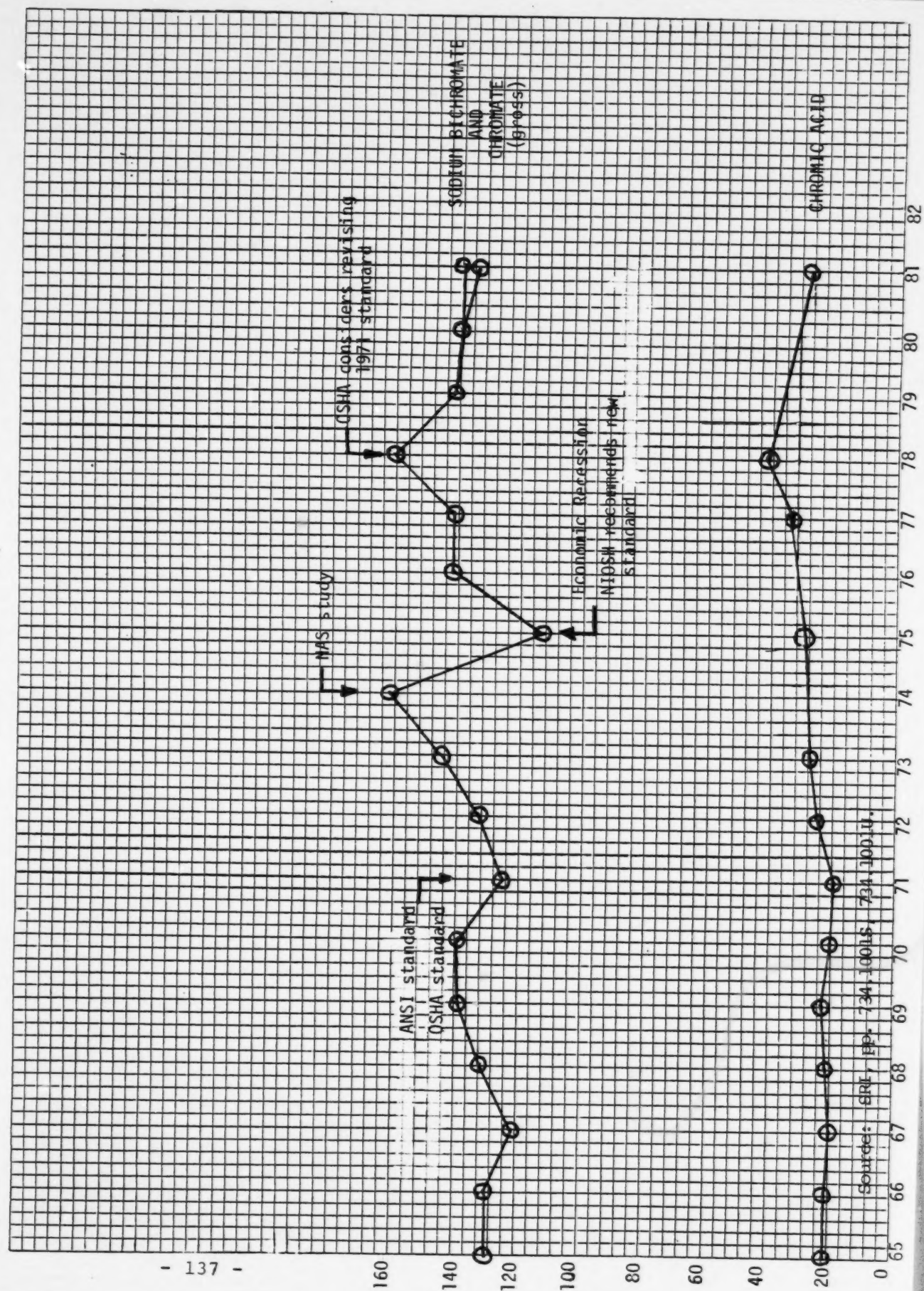
Based on the preceding summary of consumption and use characteristics, environmental concerns, and regulatory actions affecting Cr(VI) compounds, it is apparent that these compounds may pose a potential health hazard in both their production and use in many principal use categories. Therefore, both production and use categories of Cr(VI) will be examined in this analysis, using both aggregate measures of the economic performance of Cr(VI) compounds and use-specific measures of principal consumption categories for which relevant public economic data exist.

1. Production of Chromium (VI) Compounds

As indicated in the **Supply Factors** section above, sodium bichromate is the major chemical product derived from chromite (chromium ore) and is used in the production of all other chromium chemicals. Figure 1 provides data on production of chrome chemicals (indicated by gross production of sodium bichromate/chromate and chromic acid in metric tons). Illustratively, production of sodium bichromate/chromate is estimated to have been approximately 135-140 thousand metric tons in 1981, and was valued at approximately \$150-200 million. On a net basis, i.e., after subtracting the bichromate consumed in production of other chromium chemicals, sodium bichromate/chromate accounted for 65-70% of the quantity of chromite consumed, and chromic acid accounted for approximately 30%.

Production of other Cr(VI) compounds such as potassium and ammonium bichromates and chromates (not shown in Figure 1) account for only about 5% of total Cr(VI) production, largely resulting from their being significantly more

Figure 1. U.S. Production of Chromium (VI) Compounds (000 metric tons)



expensive than sodium bichromate. Table 4 shows the prices of various chromium compounds.

Table 4. Prices of Chromium (VI) Compounds (¢/lb)

<u>Year</u>	<u>Sodium Chromate</u>	<u>Sodium Bichromate</u>	<u>Chromic Acid</u>	<u>Potassium Bichromate</u>	<u>Ammonium Bichromate</u>
1970	17	15	34	21	42
1971	18	16	35	22	68
1972	20	16	35	24	68
1973	20	17	39	24	68
1974	29	21	44	24	78
1975	29	25	53	24	78
1976	29	28	58	41	78
1977	35	32	68	48	78
1978	39-53	36-37	75-78	48-55	78-127
1979	39-60	37-41	78-84	48-63	78-139
1980	39-74	37-50	78-103	48-80	78-158
1981	55-63	50-57	103-113	48-92	78-195
1982	55-63	57	118	48-92	78-195

Source: Chemical Marketing Reporter.

Production of these other compounds is substantially lower than for sodium bichromate and sodium chromate, and their uses tend to be limited to applications that require potassium or ammonium.

If sodium bichromate/chromate production can be regarded as a gauge for total Cr(VI) chemical production, Figure 1 shows that production of sodium bichromate/chromate increased from 1967 through 1970, following a 5% dip in 1967, then declined 10% in 1971. Production then climbed a total of 30% in the three years before the 1975 recession. It dipped substantially in 1975, by approximately 30%. From 1976 to 1978, production recovered, reaching the 1974 level before declining 12-15% in 1979 to the present level (approximately equal to 1970). Investigation was made as to extent to which suspect hazard and regulatory decisions affected declines in production.

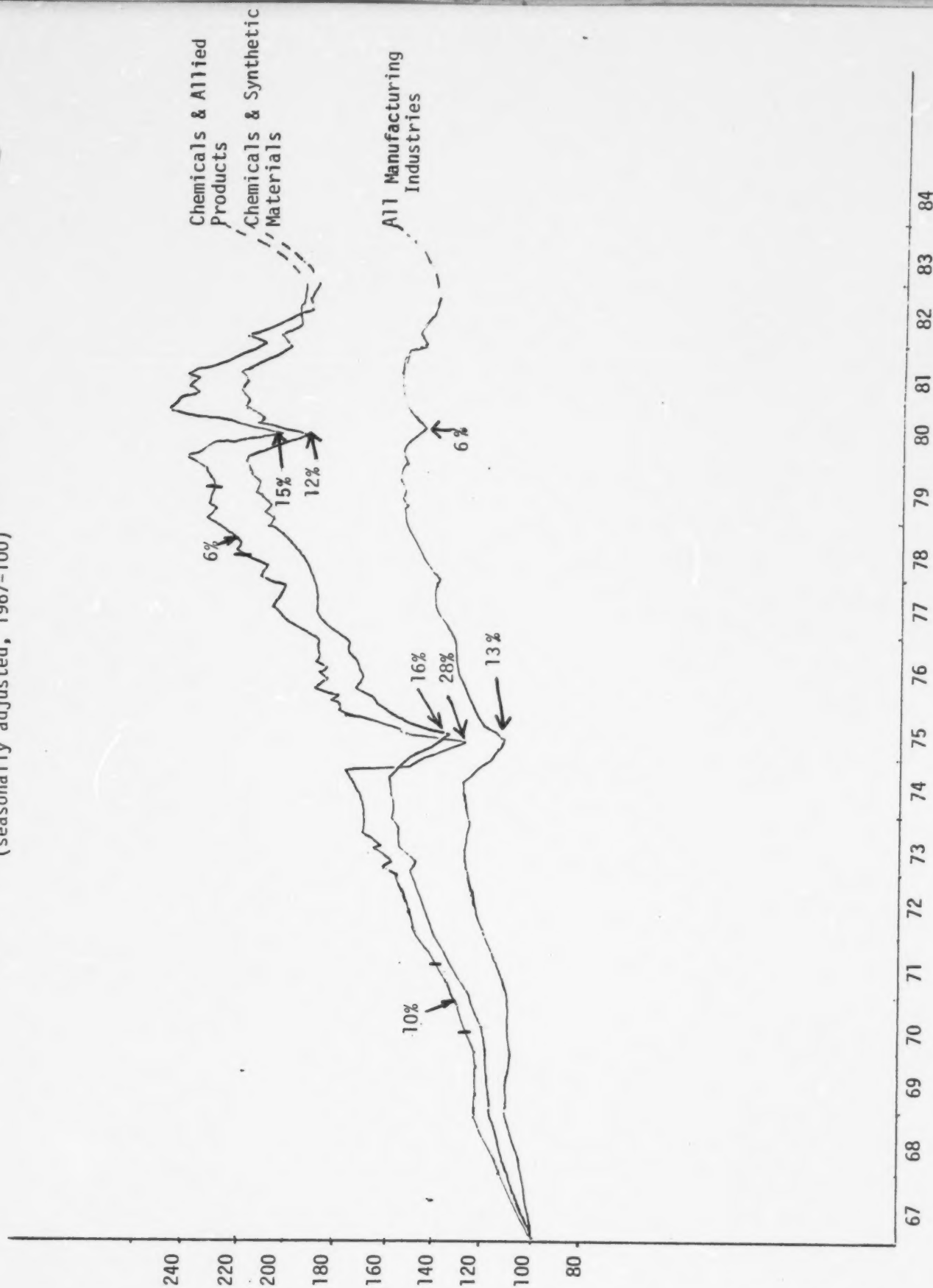
As shown in Figure 1, the regulatory actions concerning Cr(VI) compounds (in particular, the 1971 and 1978 OSHA actions) appear to correlate well with the two production declines. As noted earlier, production declined in 1971 at the time of both the ANSI and OSHA Cr(VI) standards. Production also declined in 1979, the year following OSHA's publicly announced intentions of proposing a new Cr(VI) exposure standard. According to OSHA staff, Cr(VI) producers were well aware of OSHA's ongoing intentions (first announced in 1978) to consider revising the 1971 standard and claimed that consumer demand decreased, requiring them to cut-back production (verbal communication with Elisa Bravers, OSHA staff, 8/5/83). It is not clear why these two regulatory events had different longer-term effects, i.e., production recovered after 1971 but production remained in decline after 1979. Without conducting an industry survey, it is not possible to assess how these two regulatory actions in 1971 and 1979 may have affected supplier behavior differently. It should be noted the 1980 recession (as shown in Figure 2) may simply have extended the period of decline in Cr(VI) compound production that commenced with the 1978 OSHA regulatory announcement. Examination was made as to whether regulatory factors might have explained observed declines.

Figure 2 presents indices of production changes in general economic activity in the chemical industry. These indices correlate well with the observed decline in sodium bichromate/chromate production for the year 1975, when the general Chemical and Synthetic Materials Index declined 28% compared with a 30% decline in sodium bichromate/chromate for that same year. However, the observed 1971 and 1979 declines in sodium bichromate/chromate production do not correlate with this index, for the index increased about 10% and 6%, respectively, for both years. Thus, at this scoping level of assessment, regulatory rather than general economic factors appear to offer an explanation for the 1971 and 1979 decline, but not 1975.

It should be noted that imports were not an appreciable factor influencing producer behavior in the face of regulatory pre-regulatory events—they did not significantly offset production declines in any of the relevant periods.

As Table 5 shows, imports of sodium bichromate/chromate declined to negligible levels in the mid-1970s and producers' stocks erratically fluctuated between a low of 3.0% and a high of 12.2% of production during the years given.

Figure 2. CHEMICAL & INDUSTRIAL PRODUCTION INDEX
(seasonally adjusted, 1967=100)



Source: Federal Reserve Board

Table 5. U.S. Salient Statistics on Sodium Bichromate and Chromate

<u>Year</u>	<u>Production</u>	<u>Imports</u>		<u>Producers' Stocks</u>	
		<u>Actual</u>	<u>% of Production</u>	<u>Actual</u>	<u>% of Production</u>
1965	128	16.3	12.7	3.9	3.0
1966	129	21.9	6.1	11.9	9.2
1967	122	7.4	6.1	8.3	6.8
1968	132	10.5	7.9	7.4	5.6
1969	139	5.9	4.2	7.5	5.4
1970	139	3.3	2.4	10.4	7.5
1971	125	5.8	4.6	13.0	10.4
1972	133	5.2	3.9	12.6	9.5
1973	144	0.9	0.6	6.3	4.4
1974	162	2.1	1.3	13.2	8.2
1975	113	0.7	0.6	13.8	12.2
1976	142	0.5	0.3	14.7	10.4
1977	142	0.1	neg.	8.1	5.7
1978	160	0.6	0.4	14.3	8.9
1979	142	0.5	neg.	11.6	8.2
1980	140	1.0	0.7	10.8	7.7
1981	135-140	1.5	1.0	12.8	9.1

Source: SRI, p. 734.1001S.

In 1971, production declined 14×10^3 metric tons from 1970 (10%) while both imports and stocks increased 2.5×10^3 metric tons and 2.6×10^3 metric tons, respectively, for the same year, resulting in no net additional effect on total supply, i.e., production was not supplanted by an increase in imports or a decrease in producer stocks. In 1979, production declined 18×10^3 metric tons from 1978 (11%) while imports remained negligible (less than 1% of production) and producers' stocks decreased 2.7×10^3 metric tons for the same year. However, this stock draw-down potentially accounted for only 19% of the total decline in supply in 1979.

2. Consumption of Chromium (VI) Compounds

In this section trends in the consumption of Cr(VI) chemicals for the three largest principal use categories (pigments, metal treatment, and leather tanning) and their relation to suspect hazard and regulatory designation will be examined.

a. Chromium Pigments

The production of chrome pigments accounted for 26% of total U.S. demand for sodium bichromate/chromate in 1981. As with all other principal use categories, this percentage has remained fairly constant since 1970 as shown in Table 1, fluctuating from a high of 33.3% in 1972 to a low of 26.0% in 1975. In absolute terms, production of chromium pigments increased during the early 1970s (with the exception of 1975) and has been steadily declining since 1976. Figure 3 and Table 6 summarize data on chromium pigment production. The relative constant share of pigment demand of total sodium bichromate/chromate demand shown in Table 1 suggests that the time series production curve for chromium pigments would parallel the sodium bichromate/chromate production curve. Comparison of Figure 3 with Figure 1 confirms this similarity, with the exception of the years 1976 and 1977. As with sodium bichromate/chromate production, chromium pigment production declined in 1971, then increased (21%) up to 1974, declined 31% in the 1975 recession but then immediately recovered in 1976 to about the 1974 level. From 1976 to 1980, production again declined with the greatest loss registered in 1979 (11%).

Examination of regulatory impact factors revealed that such impacts appeared generally significant. Figure 3 shows the regulatory milestones associated with chromium pigments in conjunction with the pigments production curve. As summarized in the regulatory history, chromium pigments were not singled out for regulatory scrutiny but were under the same general regulatory attention as all Cr(VI) compounds, i.e., no regulatory action was specifically aimed at chromium pigment producers or consumers. As Figure 3 indicates, the three dips in domestic production—a major one in 1975 and 1978-80 and a minor one in 1971—were all correlated with regulatory events and factors. One of those factors worth separate mention was a regulatory concern over lead exposure.

Chrome yellow, chrome orange, and molybdate chrome orange are all chromium pigments which contain lead. These three classes of chromium pigments during the late 1960s and 1970s constituted over 80% of all chromium pigments produced (SRI, pp. 520.5090B, 520.5160B). Thus it might be expected

Figure 3. Production and Imports of Chromium Pigments (000 short tons)

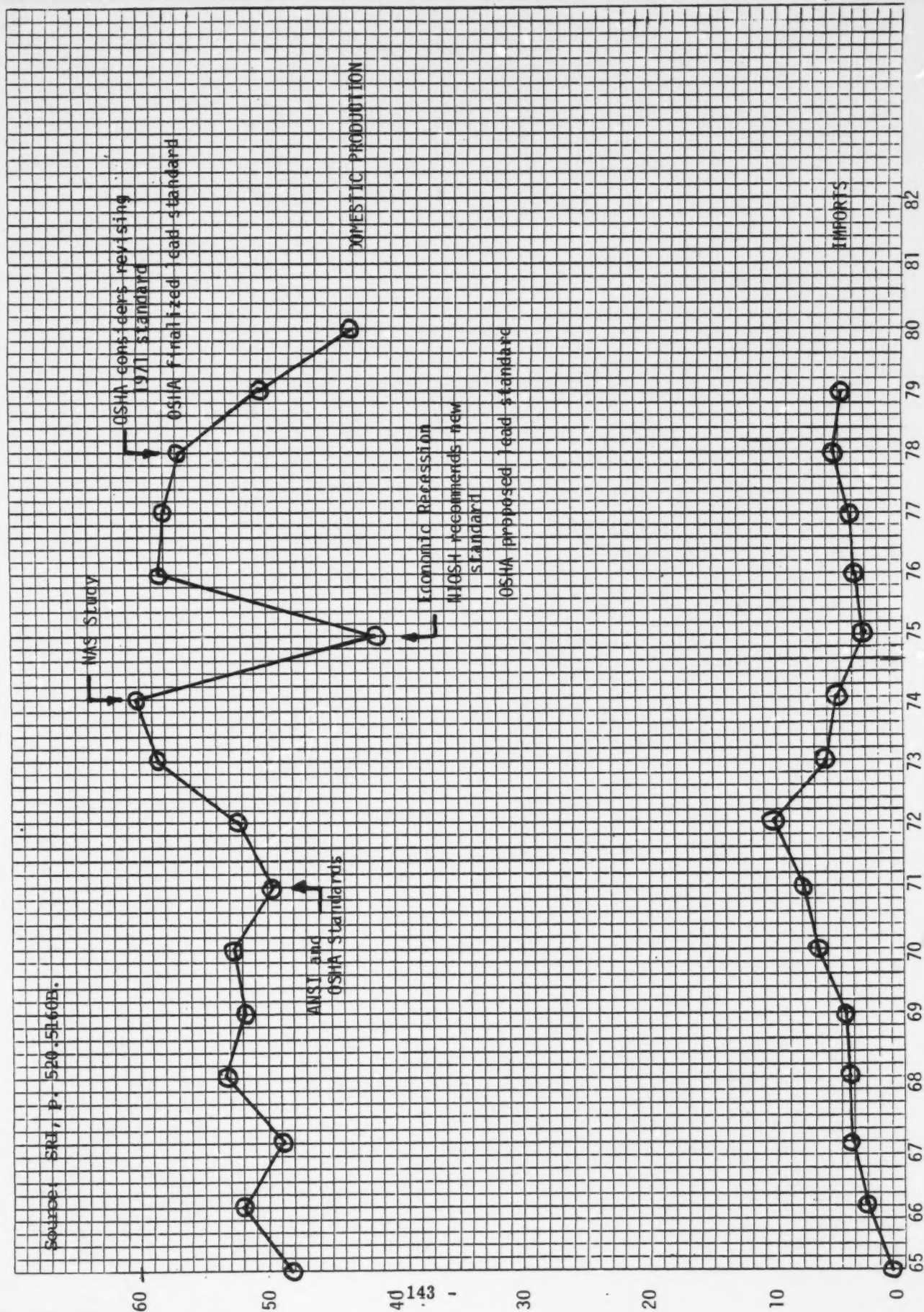


Table 6. Salient Data on Chromium Pigments

Year	Production (000 short tons)		Ratio Chromium to All Synthetics	Domestic Price (000 dollars per short ton)	Chromium Pigment Imports (000 short tons)	Ratio Imports to Chromium Pigment Production ($\times 10^{-2}$)	Price of Imports (000 dollars per short ton)	Relative Price (Dom/Imp)
	All Synthetic Inorganic Pigments	Chromium Pigments						
1965	110.5	48.16	0.44	0.77	1.09	2.3	NA	NA
1966	115.7	52.08	0.45	0.79	3.09	6.9	NA	NA
1967	117.3	48.98	0.42	0.78	4.34	8.9	NA	NA
1968	128.4	53.22	0.41	0.78	4.35	8.2	NA	NA
1969	127.9	51.86	0.41	0.80	4.67	8.0	NA	NA
1970	119.8	52.77	0.44	0.83	6.85	13.0	NA	NA
1971	119.3	49.70	0.42	0.87	7.94	16.0	NA	NA
1972	133.6	52.34	0.39	0.88	10.21	19.5	NA	NA
1973	142.5	58.48	0.41	0.89	6.11	10.4	NA	NA
1974	142.5	60.21	0.42	1.24	5.38	8.9	NA	NA
1975	93.1	41.26	0.44	1.44	3.23	7.8	NA	NA
1976	122.5	58.36	0.48	1.57	3.92	6.7	NA	NA
1977	121.7	57.98	0.48	1.73	4.20	7.2	1.17	1.34
1978	129.4	56.75	0.44	2.15	5.59	8.8	1.31	1.32
1979	139.1	50.37	0.36	2.72	4.69	8.3	1.69	1.27
1980	NA	43.34	NA	NA	NA	NA	2.15	1.26
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	

Source: Derived from SRI, pp. , 520.5090B, 520.5160B, 520.5180B.

that lead-related regulatory actions would also impact the production and/or use of chromium pigments. The major regulatory actions on lead after the 1971 OSHA lead standard were OSHA's proposal for a new lead exposure standard in 1975 followed by publication of a final new standard in 1978, which overlapped the 1978 OSHA chromium action. Hence, it is not possible to discern the difference in impact on pigment production resulting from chromium-specific regulatory actions and those actions focused on lead for that year. Also, since pigments consume around 26% of Cr(VI) compounds produced (i.e., sodium bichromate/chromate) it is not unreasonable to suspect that the 1978 lead standard was responsible for a portion of the decline in sodium bichromate/chromate production in 1979. Examination of the extent to which economic factors may explain these production declines shows that only in 1975 did these factors appear to have significant explanatory value.

In 1975, when production declined 31%, the general Chemical and Synthetic Materials Index declined 28%, indicating that almost all of the decline could potentially be explained by the slowdown in economic activity. However, if one examines another general economic activity indicator of the performance of chromium pigments—the production ratio of chromium pigments to all synthetic inorganic pigments shown in Table 6 (column 3)—its decline in 1967, 71, 78, and 79 imply that the declines in chromium pigment production during those years may not simply have been a part of the general economic performance of the inorganic pigment industry in those years and that one must look toward other factors for an explanation.

The price of substitutes was not found to have significant value in explaining production declines. It is reported that chromium pigments are relatively inexpensive, and that substitution of nonchromium pigments would involve a severe price penalty. (US BOM Mineral Facts and Problems, p. 180.) So it appears that without non-market stimuli, e.g., health considerations or regulatory actions, decreased production due to relative price advantages of substitutes is also not a factor in explaining production declines.

Thus decreased pigment activity in 1971 and 1976-80 appears to be associated with regulatory rather than economic events; whereas for 1975, economic events appear to offer an adequate explanation of observed decline.

It should be noted that suppliers did appear to take action to offset the regulation-related production decline in 1971-72 by increasing imports of chromium payments (columns 5 and 6 of Table 6). However, inspection of the same table reveals that imports did not continued to offset the 1975 and later production declines, even though they appear to have been considerably less expensive since 1976, the first year for which data were available (column 8 of Table 6). Data were not available to determine whether and to what extent domestic producers compensated for decreased production in the face of regulatory events by drawing down industry stocks.

b. Metal Treatment

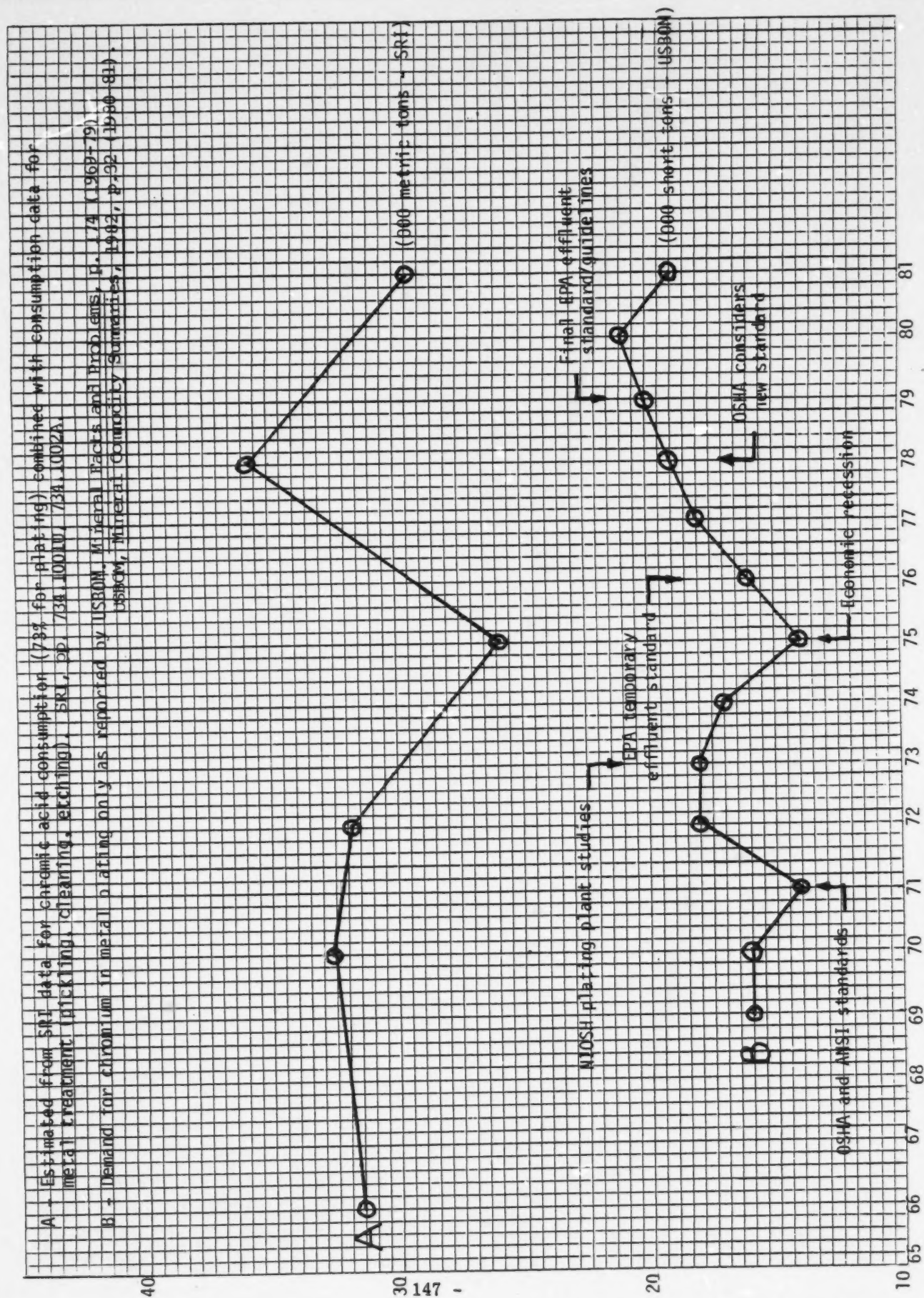
Chromium (VI) compounds used for metal treatment are utilized in several different metal finishing and processing operations, such as plating and electroplating, etching, anodizing, electropolishing, and metal spraying. Process baths and/or rinsing operations in each of these categories may contain chromic acid. The concentration and quantity of Cr(VI) utilized, and consequently the hazard posed to Cr(VI) exposure, depends upon specific plant use.

Historically, the human suspect hazard presented by chromium plating operations was from inhalation of acid mists emanating from plating tanks. More recently, however, concern has focused on reducing Cr(VI) in waste water effluents from these plants.

Figure 4 provides time series trends for the metal treatment category. Two curves derived from different data sources are shown. Points on curve A include all metal treatment applications, whereas those on curve B represents consumption of Cr(VI) for metal plating only. Thus curve A points are larger in magnitude than those on curve B. Since both curves appear to be parallel and curve B is derived from a continuous time series whereas curve A is not, curve B was used as an indicator of chromium metal treatment activity in this analysis.

Examination of Figure 4 reveals that two regulatory and suspect hazard events—the OSHA and ANSI standards (1971) and the NIOSH plating plant studies (1973) appear to be associated with declining metal plating consumption, while three others—the EPA temporary effluent standard (1976), consideration by OSHA of a new standard (1978) and final EPA effluent standard guidelines (1979) do not appear to be associated with declines.

Figure 4. Consumption of Chromium (VI) in Metal Treatment



To examine the possible impact of economic events or factors on these movements, each of the events and periods may be considered in order. The 1971 and 1973-74 declines in consumption do not appear to be associated with declines in relevant indices or economic activities. Comparison with the chemical and synthetic materials index of Figure 2 (which includes organic chemicals) shows no correlation: the index increased 10% in 1971 and moved upward as well as through 1974.

For 1975, comparison of chromium compound consumption with the chemical and synthetic materials index of Figure 2 shows a differing pattern of decline. The index declined 28% in 1975 and completely recovered a year later. In cost, consumption of Cr(VI) in metal plating declined 22% between 1973 and 1975 and recovered more slowly. The 1976 issuance of the EPA waste water effluent standards for plating plants may thus have dampened the economic recovery of this industry, as evidenced by the lower rate of recovery between 1975 and 1976 compared with a complete rebound in the index of Figure 2 in 1976.

For 1978-79 the impact of regulatory events is less clear.

The 1978 OSHA action and the 1979 EPA actions directed at the plating industry appear to have had no impact in decreasing consumption of Cr(VI) for metal plating. One explanation for this may be that the availability of proven, economical engineering controls and techniques for recovery or removal of Cr(VI) from effluent waste water was greater then compared with the early 1970s. A review of the literature on this subject seems to bear out this hypothesis. As early as the 1940s, local concern over occurrence of chromium in ground water (e.g., Nassau Co., N.Y.) near metal plating waste disposal basins resulted in U.S. Public Health Service and U.S. Geological Survey investigations and reports on the dispersal of these wastes in the 1950s and 1960s. As a result, some local regulations (e.g., the Connecticut Water Resources Commissions Order No. 479 in October 1967) were issued that directed plating plants to install adequate facilities to treat all water-borne wastes. In 1971, the EPA published an investigation of techniques best adapted technically and economically for removal of chromium from electroplating waste. In 1972-73 a demonstration grant was given by the EPA to a Connecticut-based plating company for the purpose of

installing and demonstrating the use of a waste treatment system. Other EPA-funded reports and U.S. Bureau of Mines research on techniques for removal of chromium wastes were published in 1978 and 1979 (See Bibliography). The extent and the time-table by which such waste recovery techniques have been employed in plating operations is not known in the absence of an industry survey. However, it was reported (Kirk-Othmer, v. 6, p. 102) that:

The adoption of standards in 1971 established design parameters for plants. Complete enclosure of operations and maintenance of negative pressures within equipment to prevent escape of dust or mist are now required. As standards for effluents and control of the work area have tightened, newer plants have improved techniques further. Consequently, investment in designs satisfying environmental requirements has increased sharply. All wastes must be processed to either recover or precipitate (remove) chromate before discharge.

Investments in engineering control techniques to recover/remove wastes would over time allow plating operations to maintain or increase plating activity (and consumption of Cr(VI)) in spite of stricter emission standards, and could thus explain the increased consumption activity observed here. On the other hand, such investments might also increase operating efficiency so that either less Cr(VI) was lost to waste or more Cr(VI) was recovered and recycled into the plating baths, thus reducing Cr(VI) feedstock consumption requirements. For example, air scrubbers have been incorporated in ventilating exhaust systems installed in some metal treatment plants to recover chromic acid mist and recycle it to the chromium plating bath (Booz, Allen and Hamilton, 1975). Meaningful assessment of regulatory impact would require a more detailed analysis of these factors.

Examination of the role of the price of substitutes on chromium consumption in this use showed little potential for impact. US BOM, Mineral Facts and Problems, p. 175, states that there is no satisfactory alternative for chromium in industrial plating applications and that except when the deposited metal is very expensive, e.g. gold, the actual cost of the deposited metal is a minor factor in the total cost of electroplating (Kirk-Othmer, v. 8, p. 835). Thus a switch to less-costly substitutes is not a likely explanatory factor for observed declines in consumption.

Likewise, increased imports and/or depletion of industry stocks were not factors explaining consumption changes because chromium plating solutions are formulated on site using chromic acid and catalysts to assure proper concentrations, pH, and temperature.

c. Leather Tanning

Extensive data on Cr(VI) consumption for leather tanning were not readily available from public sources. Consumption of Cr(VI) for this application, as shown in Table 1, has remained relatively constant. However, given the discontinuous time series in that Figure, it is not possible to determine how Cr(VI)-specific regulatory actions may have affected this principal use category. The 1978 OSHA action proposing that a general chromium (VI) occupational standard revision be made might well have led to the slight consumption decline observed between 1978 and 1981, but without a more complete time series, it is not possible to estimate impact.

Leather tanning operations are similar to the metal treatment application in that local waste effluent surveys were conducted throughout the 1950s and 1960s with waste treatment processes being developed and tested with federal government funding (e.g., the Federal Water Pollution Control Administration - 1969) to meet local stream classification standards. The fact that Cr(VI) is not present in leather tannery waste waters as a result of the chemical reduction of Cr(VI) to Cr(III) in the tanning process, would imply that local concern over chromium in any form, toxic or nontoxic, found its way early on into specific tannery applications and, as with metal treatment, that impact of federal regulation in later periods would be difficult to assess.

F. **SUMMARY**

In summary, chromium (VI) compounds have been subject to a rather long history of occupational injury associated with their production and use in all principal use categories, compounded by some evidence of human carcinogenicity. The regulatory actions associated with Cr(VI) compounds constituted what can be considered as three periods, the first two (1943-1972 and 1975-present) bearing on all occupations and work places where there is exposure

to Cr(VI) compounds while the third period (1973 to present) focused on metal treatment operation.

To assess the impact of this regulatory scrutiny, trends in the production and consumption of Cr(VI) compounds in three principal use categories were examined together with supply factors for chromium pigments, metal treatment (plating), and chrome leather tanning.

Regulatory actions appeared to be associated with declines not accounted for by economic factors in 1971 and 1979 in the production of Cr(VI) compounds and the production of chromium pigments. A complicating factor entering into interpretations of chromium pigment data was lead-related regulatory actions (1975-1978). Lead is contained in 80% of all chromium pigments.

For metal treatment, the 1971 and 1973-74 Cr(VI) consumption decline and the U-shaped 1975 recession dip seem to be associated with regulatory actions in 1971, 1973 (plating-specific), and 1976 (plating-specific). However, no effects were observed as a result of regulatory actions occurring in 1978 and 1979 (plating-specific), quite possibly because of the increased availability of economical waste treatment techniques for recovery/removal of Cr(VI) in plating waste.

Extensive and complete data for chrome leather tanning were not readily available. Thus an estimate of regulatory impact on this category was not possible.

SECTION II.7

REGULATORY IMPACT ANALYSIS FOR FORMALDEHYDE

The purpose of this summary is to report on the potential market impact of designating formaldehyde as a suspect toxic hazard. An estimate of such impact depends on careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. INTRODUCTION

Formaldehyde is one of the most commonly used chemicals in consumer products. It is used in such diverse products as plywood, particleboard, permanent press clothing, home insulation, cosmetics, and embalming fluid. Most formaldehyde produced in the world and all of that produced in the United States is made from methanol by either a combination oxidation-dehydrogenation process or by catalytic oxidation in the vapor phase. Formaldehyde has been associated with cancer in rats, according to various tests. It can also cause eye irritation, respiratory problems, and allergic reactions in humans. Particular regulatory attention has been drawn to its release or "offgassing" from products manufactured from it, notably particleboard and paneling used in manufactured homes and insulation made of urea-formaldehyde foam. In addition, certain miscellaneous uses of formaldehyde in specific chemical compounds used to treat apparel and as detergent builders have been designated suspect hazards at one time or another.

B. CONSUMPTION AND USE CHARACTERISTICS

Exhibit I shows domestic consumption of formaldehyde over time. Consumption grew at an average annual rate of 4% during the 1969-1981 period. This rate is well below the 9.6% rate experienced during the previous decade, reflecting a tendency toward maturation and the effects of the economic recession in 1974-1975.

EXHIBIT I

U.S. CONSUMPTION OF 37% FORMALDEHYDE
(thousands of metric tons)

<u>YEAR</u>	<u>CONSUMPTION</u>
1960	898
1961	951
1962	1,085
1963	1,148
1964	1,284
1965	1,406
1966	1,682
1967	1,675
1968	1,943
1969	1,990
1970	2,000
1971	2,041
1972	2,549
1973	2,904
1974	2,599
1975	2,055
1976	2,455
1977	2,724
1978	2,826
1979	2,916
1980	2,515
1981	2,599

Source: SRI, p. 658.5033D.

Exhibit II summarizes domestic consumption of formaldehyde by major end use in 1981. Several uses are discussed in greater detail, as follows:

Urea-Formaldehyde Resins: In 1981, 27% of the formaldehyde consumed in the United States was used to make urea-formaldehyde resins. These resins have their largest use as adhesive materials in wood products, principally particleboard, medium-density fiberboard, and hardwood plywood. These uses accounted for 81% of the total urea-formaldehyde resins consumed in the United States in 1981. Future growth of urea-formaldehyde resins depends on the production of particleboard and medium-density fiberboard and on the impact of recent regulatory activity concerning formaldehyde emissions in mobile homes (U.S. Department of Housing and Urban Development, 1983.). Other uses for urea-formaldehyde resins include paper and textile treatment, molding compounds, surface coatings, and foam insulation. As will be discussed below, there seems to be little future for urea-formaldehyde insulating foam since the Consumer Product Safety Commission (CPSC) banned its use in residential homes and schools in 1982. Overall, U.S. consumption of urea-formaldehyde resins is expected to grow at an average rate of 3% per year through 1986.

Phenolic Resins: Phenolic resins are the second largest market for formaldehyde, accounting for approximately 20% of consumption in 1981. They are produced by condensation of phenol or substituted phenol with formaldehyde. Raw materials represent a significant part of production costs. Significant end uses are in plywood production, thermal and sound insulation (where approximately 80% of the resins currently used are for binding glass fiber), and molding compounds. Phenolic resins are a potential substitute for urea-formaldehyde resins in the non-structural particleboard binders market, although urea-formaldehyde resins are only half as costly and require less curing time.

Acetylenic Chemicals: One very large end use for formaldehyde is in the production of acetylenic chemicals of which 1,4-Butanediol is the most important chemical in this group. This chemical is particularly used for solvent applications, as well as to produce chemicals used in consumer and pharmaceutical applications such as cosmetics, hair sprays, and germicides.

EXHIBIT II
U.S. CONSUMPTION OF FORMALDEHYDE BY END USE
1981, Millions of Pounds

Urea-Formaldehyde Resins	1,521
Phenolic Resins	1,121
Acetylenic Chemicals	480
Polyacetal Resins	450
Pentaerythritol	386
Hexamethylenetetramine	315
Urea-Formaldehyde Concentrates	300
<u>Miscellaneous</u>	
Methylenebis (4-phenyl isocyanate) (MDI)	225
Melamine Resins	205
Chelating Agents	160
Textile Treating Applications	90
Trimethylolpropane	82
Pyridine Chemicals	75
Nitroparaffin Derivatives	25
Trimethyloethane	25
Other	<u>269</u>
 Total ^a	 5,729

^a Total may not equal the sum of the columns because of rounding.

Source: SRI, p. 658.5031F.

Polyacetal Resins: Polyacetal resins, also called acetal or polyoxymethylene resins, are thermoplastic engineering resins that are used in a variety of applications, where fabricated metal parts would once have been used. They are derived by the anionic polymerization of formaldehyde or its trimer, trioxane. Because polyacetal resins have the highest balance of strength and stiffness among unreinforced thermoplastics and have other properties such as low coefficient of friction and good dimensional stability, they are often used to replace metals in mechanical working components of appliances, automobiles, industrial machinery, and in hardware. Consumer items that can contain acetal resins include aerosol valves, cassettes, pens, zippers, knife handles, and disposable cigarette lighters. Polyacetal resins are also widely used in plumbing applications.

Pentaerythritol: This chemical is produced by the alkaline condensation of formaldehyde and acetaldehyde. It is mainly used in the production of alkyd resins for the protective coatings industry as well as the production of short-chain fatty acid lubricants used for gas turbine engines for jet aircraft and high performance vehicles. Other uses include rosin and tall oil esters, used in adhesives, flooring materials, inks, and surface coatings; explosives; and chlorinated polyethers for the plastics industry.

Hexamethylenetetramine (HMTA): This chemical is produced by reacting aqueous formaldehyde with liquid or gaseous ammonia. The largest end use is the production of nitrilotriacetic acid (NTA) and its salts, used as a chelating agent and as a builder in synthetic detergents. NTA began to be used as a builder in laundry detergents in the mid- to late 1960s as replacement for phosphorus-containing builders, after certain state and local legislation limited (or banned) the use of phosphates in synthetic detergents. In 1969, 100 million pounds of formaldehyde were used in the production of NTA (industry estimate). In 1981, an estimated 60 million pounds of NTA were produced in the United States. Of this total, 10 million pounds were consumed domestically (for industrial applications) and about 50 million pounds were exported to Canada. The second largest use is in phenolic thermosetting resin curing agents, a use which is strongly tied to the

health of the construction and automotive industries, which are the largest consumers of phenolic resins. HMTA is also used in several miscellaneous applications such as rubber accelerators, intermediates for the production of insecticides and pharmaceuticals, and as a textile-treating agent.

Urea-Formaldehyde Concentrates: Urea-formaldehyde reaction products are used as sources of controlled release (or slow release) nitrogen in fertilizers produced primarily for nonfarm markets such as lawns, turfs, and nurseries. Solid UF products are comprised of unreacted urea, short-chain UF compounds, and longer-chain linear and cross-linked polymers.

Melamine Resins: Melamine resins are thermosetting resins produced from melamine and formaldehyde. The degree of polymerization depends on the pH of the reaction mixture, and heat is always needed for curing. These resins are mainly used for surface coatings, with typical applications including: appliance finishes, automotive topcoats, coil coatings, container coatings, furniture finishes, coatings for other metal and wood surfaces, and paper and textile products. Another large use of these resins is in decorative laminates, mainly used in inexpensive furniture such as the manufacture of tabletops, counter tops, and in wall paneling. Melamine resins are also used in compression molding compounds for dinnerware, as well as in paper and textile treating, and as binders for wood products such as plywood.

Use in Textile Treating Compounds: Formaldehyde is used alone and in the form of its derivatives to impart wrinkle resistance to fabrics. Consumption of formaldehyde for use in textile treating applications was estimated at 90 million pounds in 1981. Its principal application has been in postcure durable press resins for use on cotton blends. Additional demand is created from use in durable press resins for treating shirt cloth and to make fabrics crease resistant. As will be discussed below, there has been considerable publicity over formaldehyde emission and toxicity for textile treating applications. In addition, the release of free formaldehyde in fabric cutting rooms and warehouses has been a problem in the textile industry.

Miscellaneous Uses: Formaldehyde is consumed in several miscellaneous uses, including: the production of compounds used to manufacture rigid polyurethane foams; urethane surface coatings; reinforced plastics and specialty alkyds; synthetic lubricant base stock; pyridine and nitroparaffin chemicals and derivatives; dyes; as an embalming agent; and in drilling muds as a starch preservative.

C. SUPPLY

Most formaldehyde produced in the world and all of that made in the United States is produced from methanol by either a combination oxidation-dehydrogenation process or by catalytic oxidation in the vapor phase. The two competing processes are based on a silver catalyst or on a metal oxide catalyst. During the last decade, no new processes have emerged, but refinements have continued to be made on both processes. Each process is practiced in a number of variations, most of which are available from licensors. Exhibit III presents a picture of U.S. supply and demand for 1980 and 1981.

Formaldehyde is currently produced in the United States by 13 companies. In general, formaldehyde is not expected to be in tight supply during the next five years, given adequate supplies of methanol. However, there may be localized shortages of formaldehyde since it is not usually shipped great distances, and sometimes production in a given region does not equal demand.

Generally, formaldehyde plants in the United States are located in the areas where formaldehyde is consumed. For this reason, formaldehyde production capacity is distributed throughout the country. The Gulf Coast, with fourteen plants and 40% of U.S. capacity, is the region of highest production. Tight supplies and increasing prices for methanol since the oil embargo in 1973 have contributed to a 395% rise in the average U.S. price for formaldehyde between December 1973 and 1982. Although methanol prices in this period have risen faster than formaldehyde prices, the latter have been closing the gap since 1977, when methanol prices began to stabilize as a result of increased imports from Canada.

EXHIBIT III

U.S. SUPPLY AND DEMAND FOR 37% FORMALDEHYDE 1980, 1981, Millions of Pounds

	<u>1980</u>	<u>1981</u>
Production	5,555	5,721
Imports	10	19
Exports	19	11
Total Apparent Domestic Demand ^a	5,546	5,729
Total Actual Domestic Demand	5,546	5,729
Total Capacity (January 1)	8,503	8,438
Production/Capacity Ratio	0.65	0.68

^a Calculated as production plus imports minus exports.

Source: SRI, p. 658.5031E.

D. REGULATORY HISTORY

In certain uses formaldehyde causes irritation on contact with the skin, eyes, nose, throat, or lungs, and exposure also may cause sensitization in susceptible individuals. Formaldehyde has also been reported as carcinogenic in mice and rats. Thus, it has been the subject of considerable regulatory attention, mainly in certain specific uses but also more generally as well.

1. General Suspect Hazard Designation

In the United States, in 1976, the Occupational Safety and Health Administration (OSHA) set a limit for formaldehyde exposure of three ppm on the basis of an eight-hour time weighted average (TWA), with a ceiling concentration of five ppm. Since 1977, the American Conference of Governmental Industrial Hygienists (ACGIH) has recommended an exposure limit of two ppm (TWA). This recommendation has no force of law, but has been followed by some companies in the industry. The National Institute of Occupational Safety and Health (NIOSH) since 1976 has recommended a 30-minute concentration of one ppm for formaldehyde in the work place.

In 1978, preliminary results of testing by the Chemical Industry Institute of Technology (CIIT) indicated formaldehyde caused cancer in rats (HUD, 1983, p. 37139).

In 1980, the Inter-agency Regulatory Liaison Group (IRLG) declared its intention to examine formaldehyde products and exposure because the chemical can be released or "offgassed" from products manufactured from it.

In February 1982, the U.S. Environmental Protection Agency (EPA) announced that it was removing formaldehyde from the list of potential candidates for regulation under Section 4(f) of the Toxic Substances Control Act (TSCA), which requires that the substances be identified for regulation and deadlines set for regulatory decisions.

2. Suspect Hazard Designation for Specific Uses

Formaldehyde has been designated a suspect hazard in four specific uses. These are: (a) UF resin use in mobile homes; (b) UF resin use in insulation; (c) use in chelating and laundry detergent compounds; and (d) use in textile treating applications. Each shall be discussed in order.

UF Resin Use in Mobile Homes: In June 1977, a University of Washington study showed high levels of formaldehyde emissions from particleboard and paneling used in manufactured homes. This study was followed in 1979 by a National Academy of Sciences report confirming these results. Specific emissions control regulations for manufactured housing were issued in 1978 and 1979 by the states of Wisconsin and Minnesota (HUD, 1983, p. 37138). In 1980, the Department of Energy indicated its intention to regulate in this area, and the IRLG also announced its own regulatory interest. Perhaps the most important suspect hazard designation, however, was an Advanced Notice of Proposed Rule-making (ANPR) issued by the Department of Housing and Urban Development (HUD) in early 1981, and the proposed formaldehyde "off gassing" product standards on particleboard and hardwood plywood in mobile homes published in August of 1983.

UF Resin Use in Insulation: In 1977 and 1978, widespread publicity was accorded various studies of carcinogenic and other health impacts associated with UF foam insulation, and the health divisions within various states (e.g. Connecticut, Massachusetts) began to receive and take note of numerous consumer complaints that formaldehyde emissions were causing such symptoms as: eye, nose, and throat irritation; GI tract symptoms; headache; skin problems; and some miscellaneous complaints, such as fatigue, aches, and swollen glands. This led in 1979 to a ban on foam insulation in the state of Massachusetts, and to stepped-up investigative activity on the part of the CPSC. In August 1979, CPSC issued a consumer advisory on UF foam insulation, and indicated that its staff was actively considering a possible ban. In early 1981, CPSC announced a proposed ban, issuing it thirteen months later.

UF Use in Chelating and Laundry Detergent Compounds: In 1970, the National Cancer Institute published a report, "Bioassays of Nitrilotriacetic Acid (NTA) and NTA, Trisodium Salt, for Possible Carcinogenicity." This study, based on laboratory animals, presented evidence implying that NTA might be associated with carcinogenic or teratogenic activity in humans upon prolonged exposure. The following year, the U.S. Surgeon General requested detergent formulators to voluntarily cease using NTA, and in 1973, EPA held an informal meeting with detergent formulators. These events were accorded significant and widespread publicity. This designation of NTA as a suspect hazard was never formally followed by formal regulatory action.

In mid-1980, EPA reversed NTA's decade-old suspect hazard designation. It reported that although laboratory studies suggested that NTA may be linked to cancer in laboratory animals, the risk to humans exposed to it from detergents was extremely low. As a result, the EPA said it would not oppose renewed use of NTA in laundry detergents in the United States.

Formaldehyde in Textile Treating Applications: In 1979, NIOSH indicated its concern with the release of free formaldehyde as a possible carcinogenic threat to workers in fabric cutting rooms and warehouses in the textile industry. In 1981, CPSC announced that it was studying the use of formaldehyde in textile treating applications.

E. ANALYSIS OF REGULATORY IMPACT

In this section we examine the impact of suspect hazard designation on three specific uses which have come under scrutiny and/or regulation. These are: (a) UF resin use in insulation; (b) use in chelating and laundry detergent compounds; and (c) use in textile treating applications.

1. UF Use in Insulation

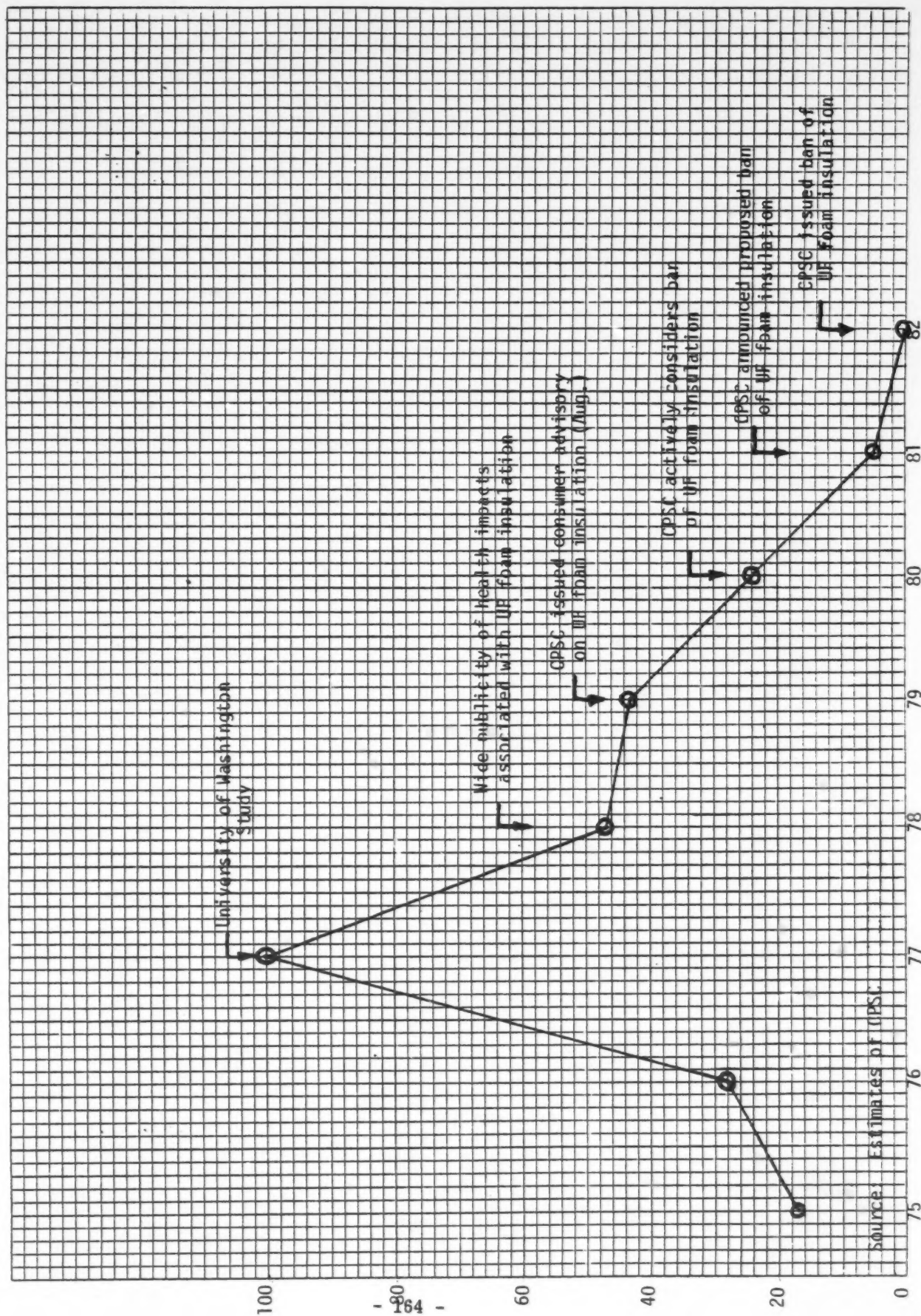
Exhibit IV shows the precipitous downward trend in U.S. domestic consumption of UF foam insulation between 1977, the year of peak consumption in response to the energy crisis, and 1982, the year that the CPSC ban took affect. Regulatory events leading up to the CPSC ban are also shown. As the Exhibit indicates, in 1978, the first year after health impacts received their initial wide publicity, UF foam insulation consumption declined by 53%, from 100 million lbs. to 47 million lbs. The decline slowed in 1979 (despite a CPSC consumer advisory issued in August), but accelerated in 1980 when CPSC announced its active consideration of a possible ban. In 1981, when the proposal to ban UF foam insulation was announced, total production fell to 5 million lbs.; and by the time that the actual ban was announced in early 1982, production had fallen to zero*.

However, because the oil supply disruptions of 1973 and 1979 resulted in increased building heating/cooling costs and a subsequent consumer demand for more energy efficient dwellings, it is possible that consumption of UF foam insulation might have fluctuated with this demand. To test this hypothesis, UF foam data was examined from the perspective of economic activity in the insulation industry. At its high point in 1977, based on DOE estimates**, UF foam was the insulation of choice by consumers for 9.8% of a total of 1.73 million residential wall retrofit insulation jobs. By the first year of suspect hazard designation, with the health alert of 1978, its share of the total insulation market had fallen to 5.4% of the total of 1.48 million insulation jobs; and by 1981, its share had fallen further to less than 1% of 0.7 million insulation jobs. This decline had grave consequences for a number of UF foam insulation manufacturers. In 1979, the year prior to CPSC's announcement of its proposed ban, there were 34

* Verbal communication with CPSC staff member with reference to CPSC Briefing Packages, 1980 and 1982.

** Department of Energy, Residential Energy Consumption Survey, 1980 and 1982.

Exhibit IV. Domestic Consumption of Urea-Formaldehyde Foam Insulation (mill. lbs.)



manufacturers. By late 1981, there were over six remaining; and by late 1982, when the ban was scheduled to take effect, there were none.

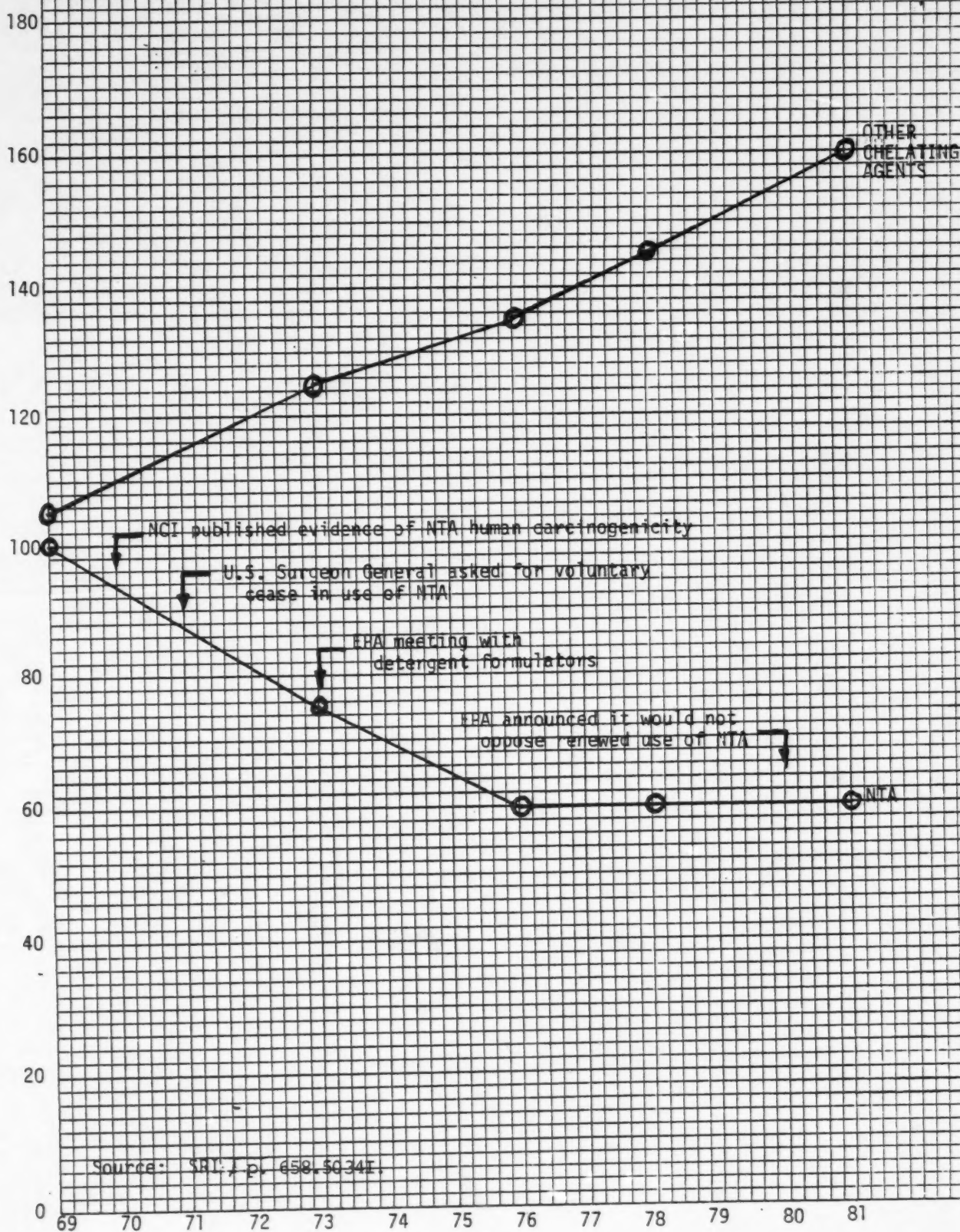
All parties with an interest in regulatory scrutiny of UF foam — government, academia, and industry — have agreed that its designation as a suspect hazard, first by the press and the state of Massachusetts reacting to carcinogenic research findings, then by CPSC, was almost entirely responsible for the dramatic decline. The ready availability of high performance, competitively priced alternative materials such as fiberglass and rock wool, produced in a highly competitive environment where capacity had been overbuilt to respond to the energy crisis of the mid-70s, made possible a faster shift away from UF foam than might have otherwise occurred. This higher degree of substitutability made UF foam virtually disappear as an insulation material because of its suspect hazard designation.

2. UF Use in Chelating and Laundry Detergent Compounds

The second use of formaldehyde that has come under suspect hazard designation is as a feedstock for production of the compound trisodium nitrilotriacetate ($\text{N}(\text{CH}_2\text{COONa})_3$, usually called NTA) which serves both as a chelating agent and as a builder in laundry detergents. NTA began to be used as a builder in laundry detergents in the mid- to late 1960s as replacement for phosphorus-containing builders, after certain state and local legislation limited or banned the use of phosphates in synthetic detergents.

Exhibit V presents an industry estimate of formaldehyde used in the production of NTA and the consumption of other competitive chelating agents for selected data-available years in the period 1969-81, together with a history of formaldehyde's designation as a suspect hazard in the NTA use. As the Exhibit shows, between 1969-76, consumption of NTA declined by 40%, while that of substitute chelating agents rose by approximately the same amount. According to industry sources, these substitutes have always been readily available at comparable prices. Although year-by-year data are not available, the decline in

Exhibit V. Estimated U.S. Formaldehyde Consumption for NTA, Other Chelating Agents
(mill. lbs.)



Source: SRI, p. 658.5034I.

NTA relative to competitive chelating agents appears to be significantly correlated with NTA's designation as a suspect hazard as a result of a 1970 NCI study followed by a subsequent request in 1971 by the Surgeon General asking detergent formulators to voluntarily cease using NTA until further testing was completed. These events were accorded significant media publicity at the time they occurred.

These data, however, significantly understate the impact of suspect hazard designation on U.S. consumption in this chelating agent/detergent use. This is because, according to industry spokesmen, most if not all NTA after the suspect hazard designation was used either for industry application or for export to Canada and Western Europe, where demand continued to grow and similar suspect hazard designation did not exist. Although precise data for these phenomena are not available, it is thus probable that the voluntary decline in domestic home detergent use was much steeper than Exhibit V indicates.

Although NTA was removed by EPA from the suspect hazard list in mid-1980, relative consumption data for 1981 do not show a renewed use of the substance.

3. Formaldehyde in Textile Treating Applications

Since announcement by CPSC in 1981 that it was studying the use of formaldehyde in textile treating applications, and given the continuing concern by OSHA with release of free formaldehyde in fabric cutting rooms and warehouses in the textile industry, there has been and continues to be significant impact on its use in these applications. Although no quantitative data are available, compounds have been reformulated for permanent press fabrics in ways that significantly economize on the use of formaldehyde, according to industry sources. Thus, there seems to have been and continues to be a substantial impact on levels of consumption for this use as a result of suspect hazard designation.

Based on estimates from SRI (p. 658.5034J), the use of formaldehyde in this application is projected to decline in real terms by an average annual rate of 2% between 1981-86. Several industry sources, however, indicate that consumption has already declined by this amount, because of suspect hazard designation by CPSC and publicity surrounding it. A specific industry survey is needed to provide more definitive data.

F. SUMMARY

In summary, the following points can be made:

- The impact of suspect hazard designation for formaldehyde as we have examined it in this study reveals itself through consideration of specific uses rather than through aggregate production series. Movements in the aggregate series simply are not correlated with designation as a suspect hazard.
- Both uses for which quantitative data are available — insulation and chelating/detergents—seems to have experienced significant declines as a result of suspect hazard designation of formaldehyde. The reasons for such impact appear to be: (a) significant consumer interest arising from media attention and the high consumer visibility of the products in questions; and (b) availability of relatively comparable substitute products or formulations.
- For the two uses for which quantitative data were available, the decline in formaldehyde use was most significant where substitutes were readily and inexpensively available, i.e. formaldehyde in foam insulation.
- With respect to the use of formaldehyde for which quantitative data were not available, i.e. textile treatment, a significant decline also appears to be occurring as manufacturers are currently reformulating low-formaldehyde or no-formaldehyde compounds for this use.

SECTION II.8

REGULATORY IMPACT ANALYSIS FOR NICKEL AND NICKEL COMPOUNDS

The purpose of this summary is to report on the market impact of designating nickel and nickel compounds as suspect toxic hazards. An estimate of such impact depends on careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. INTRODUCTION

Nickel is vital to the iron and steel industry; moreover, it has played a key role in the development of the aerospace industry. Without nickel, the sophisticated industrial complexes that provide our exceptional standard of living and superior military armamentarium would not be possible. Nickel's greatest value in alloys in combination with other elements (e.g., iron, copper, chromium, molybdenum, etc.), where it adds strength and corrosion resistance over a wide range of temperatures.

In addition to nickel metal, nickel also forms compounds in which the nickel atom has an oxidation state of +2; the states of -1, +1, +3, and +4 are also possible, but occur infrequently.* Nickel compounds have diverse physical properties.

During industrial operations, nickel and inorganic nickel compounds may escape into the environment as dusts from grinding, cutting, and melting operations; as fumes where high temperatures are involved; and as mists where nickel solutions are used. Increased risks of dermatitis from contact with nickel, especially with solutions of nickel compounds, and increased risks of cancer of the

* The "oxidation state" of a chemical element specifies the number of electrons present in its outer-most electronic shell, i.e., the least energetic electrons farthest from the atom's nucleus. The presence or absence of these electrons determines the chemical reactivity of the element.

respiratory organs from airborne forms of nickel, are the primary hazards reported from workplace exposure to inorganic nickel.

B. CONSUMPTION AND USE CHARACTERISTICS

More than 90% of nickel used in the U.S. is in the form of metal, principally in alloys. In fact, there are more than 3,000 different nickel-bearing alloys including stainless and alloy steels, ductile and cast irons, cupronickels, and high nickel alloys. Nickel's ability to resist corrosion itself and to impart corrosion resistance, strength, and specific physical properties to alloys leads to its wide use in many producer and consumer goods. Stainless steel production is the largest single application of nickel and has been the most rapidly growing use in recent years (Nriagu, 1980, p. 59).

The transportation industry as a whole, consisting of motor vehicles and equipment, aircraft, and ship building, is the largest consumer of nickel alloys (24.3%). The second largest consumer of nickel alloys is in manufacturing equipment parts exposed to corrosive chemicals in chemical manufacturing and petroleum refining industries (22.1%). Other uses for nickel alloys are in fabricated metal products, electrical machinery, and construction.

Nickel is also used in the form of compounds for which there are other, non-alloy uses such as catalysts, electroplating salts, ceramics, and other specialty chemicals. The approximate usage of nickel chemicals and an estimate of consumption for 1979 is provided in Tables 1 and 2, respectively.

The largest use category (40-50%) for nickel compounds is for catalysts. Nickel is an important hydrogenation catalyst because of its ability to chemisorb hydrogen. One important nickel catalyst is Raney nickel, used widely in laboratory and industrial hydrogenation processes. It is the most active and the least specific of the nickel catalysts. Supported nickel catalysts such as nickel carbonate, nickel hydroxide, nickel nitrate, and nickel acetate, are used for methanation, steam-hydrocarbon reforming, petrochemical hydrogenation, and fat

Table 1. Principal Use and Consumption of Nickel and Nickel Compounds (1979)

<u>Use</u>	<u>(000 tons)</u>	<u>Percent</u>
1. <u>Primary Nickel Metal (In Alloys)</u>	256.6	100.0
Chemical Industry Equipment	36.6	14.3
Electrical Machinery	34.6	13.5
Motor Vehicles and Equipment *	26.4	10.3
Aircraft Industry	25.4	9.9
General Construction	24.6	9.6
Fabricated Metal Products	24.5	9.5
Other Machinery	22.2	8.6
Petroleum Industry Equipment	20.0	7.8
Household Appliances *	18.2	7.1
Other	13.7	5.3
Ship Building	10.4	4.1
2. <u>Nickel Compounds (Less than 10% of nickel used in alloys)</u>	19-25	100
Catalysts	8-10	40-50
Plating Salts	7-9	36-37
Ceramics	2-3	10-12
Other specialty chemicals	2-3	10-12

* Includes stainless steel and electroplating

Sources: 1. USBOM; Mineral Facts and Problems, p. 618.
2. Kirk-Othmer, v. 15, p. 810.

Table 2. Principal Use and Consumption of Nickel Compounds (1979)

<u>Compound</u>	<u>Use</u>	<u>(000 tons)</u>	<u>Percent</u>
Nickel oxide sinter	Nickel alloys	50	63
Green nickel oxide	Ceramics, catalysts, pigments	10	13
Black nickel oxide	Ceramics, catalysts, pigments	5	6
Nickel sulfate	Plating	7-9	11
Nickel nitrate	Catalysts	2	2.5
Nickel chloride	Plating	2	2.5
Nickel carbonate	Catalysts, ceramics, pigments	1	1
Others		<u>1</u>	<u>1</u>
		78-80	

Source: Kirk-Othmer, v. 15, p. 810.

hardening. Nickel is used with other elements for special types of hydrogenation catalysts. Nickel sulfide and nickel tungsten sulfide catalysts are used when high concentrations of sulfur compounds are present in the hydrogenation of petroleum distillates. Nickel-molybdenum catalysts are used to denitrogenate petroleum fractions that are high in nitrogen-containing components. Efficient NO_x reduction and oxidation of hydrocarbons and CO in automobile exhaust has been achieved using nickel-iron and nickel-copper oxides, and black nickel oxide in conjunction with rhodium, platinum, and palladium catalysts.

The second largest application (36-37%) for nickel chemical compounds is as electrolytes in nickel electroplating. Nickel is electroplated from sulfamate, chloride, and fluoborate solution baths prepared with the corresponding nickel salt. A small amount of another organic chemical may be added to brighten the deposits or control another property. Nickel is extensively electroplated in a three-metal composite coating of copper, nickel, and chromium. Nickel is also electrodeposited on steel for decorative-protective finished and other materials for electroforming.

Nickel compounds, especially black or green nickel oxides are used extensively in the ceramic industry, constituting 10-12% of total compound use. Nickel oxide is added to frit compositions which are used for porcelain enameling of steel. Nickel enhances the adhesion of glass to steel. Nickel selenite, nickel phosphate, nickel tungstate, nickel chromite, potassium nickel molybdate, nickel oxide, and nickel nitrate have been used as glass colorants. Nickel oxide is employed as a colorant in ceramic body stains used in ceramic tile, dishes, pottery, and sanitary ware. Nickel oxide imparts avocado green and grey colors in ceramic glazes.

Other minor uses (10-12%) for nickel compounds are as plastic additives, pigments, and agricultural chemicals. As plastics additives, one of the important applications is as ultra-violet radiation quenchers and oxidation inhibitors in synthetic elastomers (e.g., nickel dibutyldithiocarbamate) and as flame retardant additives for polystyrene (e.g., nickel dicycloalkyldithiophosphinates). A number

of nickel-based pigments exist such as nickel antimony titanate, used extensively as a yellow chalking pigment in exterior house paint and in vinyl house siding because of its good weatherability, and nickel cobalt aluminate, used as a fade-resistant blue pigment also for exterior paint application. A number of uses for nickel chemicals as pesticides have been reported (Kirk-Othmer, v. 15, p. 814). However, extensive testing of many classes of nickel complexes in insecticide, fungicide, nematocide, and herbicide programs has shown that nickel chemicals afford little more efficacy than the non-nickel-containing derivatives. One use is as an agricultural chemical in the Far East in the application of nickel chloride as a commercial fungicide to control blister blight of tea (tea is one of the few botanical species that naturally contains nickel). Nickel sulfate is also used as an agricultural chemical to control rust in blue grass seed crops in the northwestern U.S.

C. SUPPLY FACTORS

U.S. reserves of nickel are small; however, the country possesses large resources that could be used if technological and environmental problems were resolved. The only significant recent U.S. refiners and producers of nickel are the Hanna Mining Co. and AMAX Nickel Division of AMAX, Inc. The Hanna mine, which opened in 1954, is primarily a large iron ore mining processing, and marketing company, and the nickel mine and smelter, located in Oregon, are only a small part of its overall operations. AMAX Nickel Division began production of nickel late in 1974 at its rehabilitated nickel-copper refinery at Port Nickel, La. Rated capacity of the plant is 40,000 tons of nickel with production reported at around 80% capacity annually. (USBOM Mineral Facts and Problems, p. 611).

In the early 1970s, the International Nickel Co. of Canada, Ltd. (INCO) began development of a nickel-copper mining project in Minnesota but suspended it due to proposed changes in state environmental policy toward nickel-copper development.

Domestic production of primary nickel accounts for less than 10% of the nation's peacetime demand. Recovery of scrap accounts for 20-30% of the total demand; the remaining 60-70% of U.S. demand is met from imports. U.S. imports of nickel in various forms (metal, powder and flakes, oxide and oxide sinter, ferronickel, or other) are primarily from Australia, Canada, Dominican Republic, New Caledonia, Norway, Philippines, and Republic of South Africa. The U.S. government stockpiled various forms of nickel after WW II but reduced its stockpile from 55,000 tons to zero in 1971. The stockpile had not been replenished as of 1980.

With over seventeen countries exporting nickel to the United States and the domestic nickel refinery operating at less than capacity, no supply shortages were reported.

D. REGULATORY HISTORY

1. Environmental/Human Health Concerns

The toxicity of nickel in humans has been known since the late 1800s, stimulated by clinical interest in the therapeutic use of nickel and its compounds. The first epidemiologic evidence of nickel carcinogenesis in man was revealed in 1933 among workers at a Welsh nickel refinery. Other occupational history studies of nickel refinery workers were published in the 1950s, 1960s, and 1970s in other countries including Canada, Norway, the U.S.S.R., Japan, France, Germany, and the U.S. (1973, 76). These reported respiratory cancer from inhalation of nickel sulfide, nickel oxide, nickel dusts, and nickel carbonyl vapor. However, some later studies (1949, 1958) reported that many respiratory hazards in nickel refineries had been eliminated by 1925, and that a crucial reduction in industrial exposure took place at that time.

Although the basic industrial process of refining nickel ores has not been altered since 1900, there have been progressive changes in the raw materials and in the design of industrial facilities. These changes undoubtedly affected the

composition of the dusts and fumes and greatly diminished the atmospheric concentrations of nickel to which refinery workers were exposed. To suppress the escape of dusts and fumes, improved calciners and automatic conveyors were installed in the early 1920s, followed in the 1930s by centralized grinding plants, electrostatic precipitators in the stacks, new feed elevators, and transporting devices. However, studies published as recently as 1976 produced evidence that nickel refinery workers have had an excess of deaths from cancer of the respiratory organs.

Three studies (1966,68 - France; 1973 - U.S.) reported respiratory tract cancer in workers involved in nickel plating from inhalation of electrolyte vapors and polishing and grinding dusts containing nickel. Nickel is electroplated from sulfamate, chloride, and fluorate baths. Each type of solution is prepared with the corresponding nickel salt. In addition to worker hazards with respect to vapors, waste water effluents contain nickel compounds which present problems in municipal sewage sludge disposal. However, in-process controls have been developed for minimizing dragout into the rinse, which is the major source of waste. Nickel plating baths are rarely dumped.

2. Regulatory Milestones

A threshold limit value (TLV) of 1 mg/m^3 (measured nickel) for workplace exposure to nickel metal dusts or fumes and to soluble nickel salts was proposed by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1964, and adopted in 1966. Based on this standard, OSHA issued in 1971 the present workplace exposure to nickel metal and soluble nickel salts of 1 mg/m^3 PEL. A change in the TLV for soluble nickel salts from 1 mg/m^3 to 0.1 mg/m^3 was proposed by the ACGIH in 1974 and adopted in 1976.

In 1975, the National Academy of Sciences published a study on the biologic effects of nickel for the guidance of standard-setting and regulatory agencies. Two years after this study was released, NIOSH published (May 1977) a criteria document for a new recommended occupational exposure standard of

0.015 mg/m³ TWA to nickel and its compounds based on the NIOSH conclusion that nickel/nickel compounds are carcinogens.

The first U.S. epidemiologic evidence of cancer resulting from nickel exposure was reported in 1973 in the case of a worker employed as a polisher and grinder in a nickel-plating workshop. Then in 1976, another study (U.S.) reported deaths from respiratory tract cancer in nickel alloy plant workers.

As a follow-up to the NIOSH proposed standard, OSHA published a notice in the Federal Register (Sept. 1977) requesting public comments and information on various aspects of nickel, particularly industrial production and use, and views on appropriate regulatory response to the NIOSH recommendations. As of July 1983, OSHA was still receiving public comments and no new standard has been issued.

Apart from these regulatory actions, nickel carbonyl has been singled out for special regulatory treatment because it is an extremely toxic gas. Concentrations as low as 30 ppm in air for 30 min. may be lethal for humans (Kirk-Othmer, v. 15, p. 812). Nickel carbonyl is an intermediate form of nickel in refining operations, and may form wherever carbon monoxide and finely divided nickel are brought together. Both the ACGIH and OSHA have issued exposure limits of one part per billion in air. Table 3 provides a more complete summary of regulatory events concerning nickel and nickel compounds.

Table 3. Regulatory Events Concerning Nickel and Nickel Compounds

1883	Therapeutic effects of nickel salts (nickel sulfate, nickel bromide) investigated in humans.
1889	First report of dermatitis resulting from exposure to chemicals used in nickel plating.
1933	First reported epidemiologic evidence of pulmonary carcinogenesis among nickel refinery workers (U.K.)
1964	The ACGIH proposed the first worker exposure limit (1 mg/m ³ TLV) to nickel metal dusts or fumes and to soluble nickel salts.

- 1966 The ACGIH adopted its proposed workplace exposure limit of 1 mg/m³ TLV.
- 1971 Based on the ACGIH standard, OSHA issued a 1 mg/m³ PEL workplace exposure limit to nickel metal and soluble nickel salts.
- 1973 First U.S. epidemiologic study reported pulmonary carcinoma from inhalation of nickel dust in a worker employed as a polisher and grinder in a nickel-plating workshop.
- 1974 The ACGIH proposed a new TLV of 0.1 mg/m³ for soluble nickel salts.
- 1975 The National Academy of Sciences published a monograph on the biological effects of nickel.
- 1976 The ACGIH adopted the 0.1 mg/m³ TLV for soluble nickel salts.
- 1976 Epidemiologic studies reported deaths from cancer of the respiratory organs in nickel alloy plant workers in the U.S. (W.Va.).
- 1976 The ACGIH proposed (tentatively) a TLV of 1 mg/m³ for workplace exposure to dusts and fumes of insoluble inorganic compounds from nickel sulfide ore-roasting operations (nickel-refining).
- May 1977 The NIOSH published a criteria document recommending anew occupational exposure standard of 0.015 mg/m³ TWA to nickel and nickel compounds.
- Sept. 1977 OSHA requested public comment on the NIOSH proposal.

E. ANALYSIS OF REGULATORY IMPACT

1. Nickel Refining

As noted above, there are only two nickel refineries operating in the United States and up to 70% of total U.S. primary nickel demand is supplied by imports of both refined and unrefined (ore, oxide and oxide sinter, and slurry) nickel. Hanna Mining refines nickel ore mined on-site (producing 13,000 tons of nickel in 1979) whereas the AMAX refinery produces nickel (32,500 tons in 1979) from unrefined nickel imports. Table 4 presents salient statistics on nickel production and consumption.

Table 4. Salient Statistics on Nickel Production¹ and Consumption (000 tons)

<u>Year</u>	<u>Domestic Nickel Refinery Output</u>	<u>Refined Nickel Imports</u>	<u>Refined Nickel Consumption</u>	<u>Refined Nickel Exports</u>	<u>Consumption Plus Exports</u>	<u>Industry Stock</u>
1965	13.5	132.6	146.4	20.9	167.3	NA
1967	14.6	113.9	124.6	31.5	156.1	NA
1970	15.6	117.3	112.8	31.5	144.3	31.9
1971	15.6	100.5	95.6	26.1	121.7	24.7
1972	15.7	125.4	110.4	21.7	132.1	57.3
1973	13.9	120.1	121.8	22.1	143.9	77.9
1974	14.1	137.3	124.0	30.4	154.4	71.3
1975	23.3	107.1	99.7	30.1	129.8	87.3
1976	33.9	111.3	104.4	47.2	151.6	102.4
1977	37.9	103.3	96.1	39.4	135.5	121.0
1978	37.3	147.7	123.0	36.3	159.3	145.0
1979	44.2	113.3	136.0	50.8	186.8	198.6
1980	43.7	116.2	111.6	56.7	168.3	NA
1981	47.0	123.1	101.8	46.8	148.6	NA

¹ Does not include nickel from secondary sources (e.g., scrap recovery)

Source: Predicasts Basebook, pp. 480-1; USBOM, Mineral Facts and Problems, p. 618.

Time-series trends for domestic nickel refinery output, refined nickel consumption including exports, and industry nickel stocks are juxtaposed in Figure 1, with pertinent regulatory milestones indicated. Domestic nickel refinery output has steadily increased since 1965 with only one decrease observable for the year 1973. In that year, refinery output dropped 1,800 tons (11.5%) from the previous year but then rebounded in 1974. Thereafter, it has been steadily increasing, with the exception of two small, insignificant declines of 600 tons (1.3%) between 1977 and 1978 and 500 tons (1.1%) between 1979 and 1980. Fluctuations in nickel demand, as indicated by the consumption plus exports curve in Figure 1 and the occurrence of regulatory events concerning nickel, seemingly had no deleterious impact on nickel refinery operations.

2. Nickel Alloys

Production of nickel alloys has been generally under the same blanket regulatory scrutiny as the nickel refining industry, with the exception of the 1976 epidemiologic studies, specifically reporting respiratory tract cancer in U.S. nickel alloy plant workers. Table 5 presents salient statistics on nickel used in alloys. From this table, it is apparent that nickel consumption for alloy production has fluctuated over the years, as shown in columns (a), (c), and (e). Also, it is worth noting the large absolute magnitudes of alloys produced. Because many of the year-to-year fluctuations may be due to fluctuations in general economic activity in the alloy-producing industries, ratios of nickel used in alloy production to total alloy produced were calculated for alloy steel, stainless steel, and all nickel alloys (i.e., ratios of columns (a)/(b), (c)/(d), and (e)/(f)), and are presented in Figure 2).

These data show that unit nickel consumption per unit nickel alloy output in the three alloy uses has fluctuated substantially. These three curves seem to be in general phase with each other for the year 1967-1973 and 1978-1981. Beginning in 1967, all three ratios declined and bottomed-out in 1971 (1972 for alloy steel) then increased up to 1973. In 1979, all three ratios increased from the previous year but then declined up to 1981. The only seeming correlation between

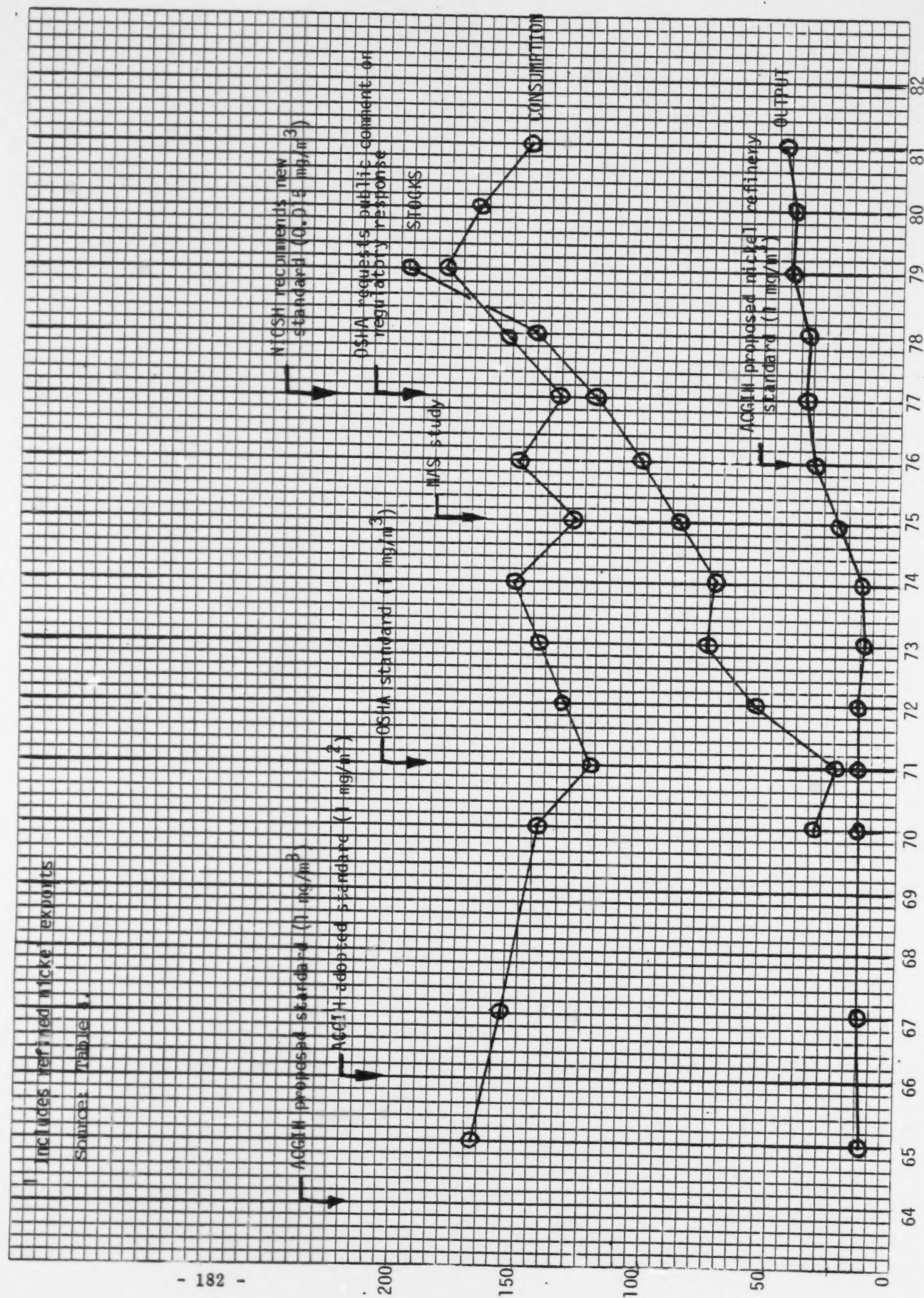
Table 5. Salient Statistics on Nickel Alloys

Year	(a) Nickel Used in Alloy Steel (000 tons)	(b) Alloy Steel Production (mill. tons)	(c) Nickel Used in Stainless Steel (000 tons)	(d) Stainless Steel Production (000 tons)	(e) Nickel Used in ¹ All Alloys (000 tons)	(f) Production of Steel Mill Products (67 Index)
1965	27.01	13.32	51.70	1493	134.25	107.6
1967	23.66	12.57	52.94	1451	124.50	100.0
1970	20.87	12.82	40.77	1279	115.60	108.7
1971	17.41	12.17	33.20	1263	94.72	97.6
1972	19.56	13.98	45.37	1564	114.63	109.9
1973	23.91	16.16	65.83	1889	148.54	127.2
1974	23.27	16.96	73.76	2150	163.38	127.0
1975	20.32	15.17	38.17	1111	112.14	99.5
1976	19.12	14.31	48.62	1684	116.73	108.9
1977	17.83	15.34	53.19	1862	121.24	105.3
1978	17.17	18.16	60.47	1954	139.97	119.4
1979	20.17	18.01	69.63	2107	156.91	120.8
1980	16.94	15.45	54.74	1701	127.04	99.3
1981	16.48	17.62	50.65	1743	111.74	109.8

¹ Includes alloy steel, stainless steel, nickel-copper alloys, and super alloys

Source: Predicasts Basebook, pp. 458, 459, 481.

Figure 1. Domestic Nickel Refinery Output, Consumption of Refined Nickel¹, and Industry Stocks (000 tons)

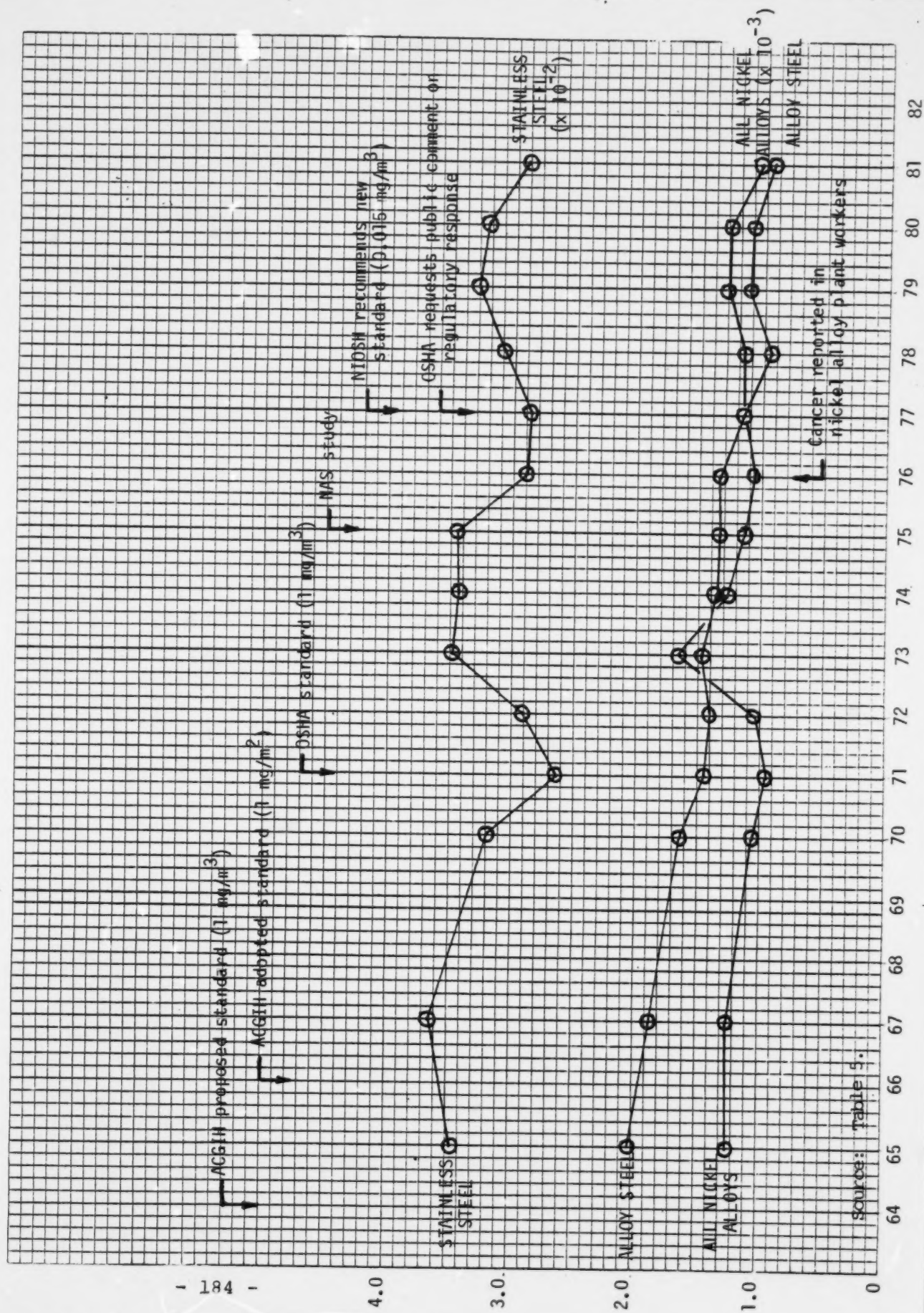


decreases in nickel used in alloys and regulatory events is in 1971, when the OSHA standard was issued. However, this standard was based on and identical to the previous ACGIH standard of 1967. The only difference was that the OSHA standard established design parameters for plants (Kirk-Othmer, v. 6, p. 102) and was enforceable by Federal law, whereas the ACGIH standard was not.

This correlation is not conclusive, for the nickel content of the alloys themselves varies according to end-use requirements. For example, in nickel-containing stainless steels (column (c) of Table 5), the nickel content has ranged from 1.25% to 37% of total chemical composition (USBOM, Mineral Facts and Problems p. 613). Nickel content in other alloys can range up to 80% nickel. Thus, any year-to-year change in amount of nickel used in producing alloys may only reflect fluctuations in end-use demand requirements for the nickel alloys, data for which are not sufficient to calculate.

One exception to this statement is nickel alloy steel (ratio of columns (a)/(b)) which may be of special interest here. In this case, nickel content has varied narrowly from 1.65% to 2.00% of total metal composition (USBOM, Mineral Facts and Problems, p. 613). Hence, fluctuation in nickel content arising from changing end-use demand requirements is probably negligible for this alloy class. Therefore, it is possible that changes in the ratio of nickel consumption used in alloy steel to total alloy steel production might be attributed to regulatory events. Figure 2 shows that the nickel alloy steel ratio has declined over most years presented, with the exception of three small one-year increases in 1973, 1976, and 1979. Because the overall trend has been downward with no marked declines observable for any particular year, it is not possible to discern or associate any impact arising from a particular regulatory event other than the 1971 OSHA standard, as mentioned above. Rather, all regulatory events might have impacted nickel alloy steel in a cumulative way.

Figure 2. Ratio of Nickel Used in Alloys to Total Nickel-Alloy Production



3. Production of Nickel Chemicals

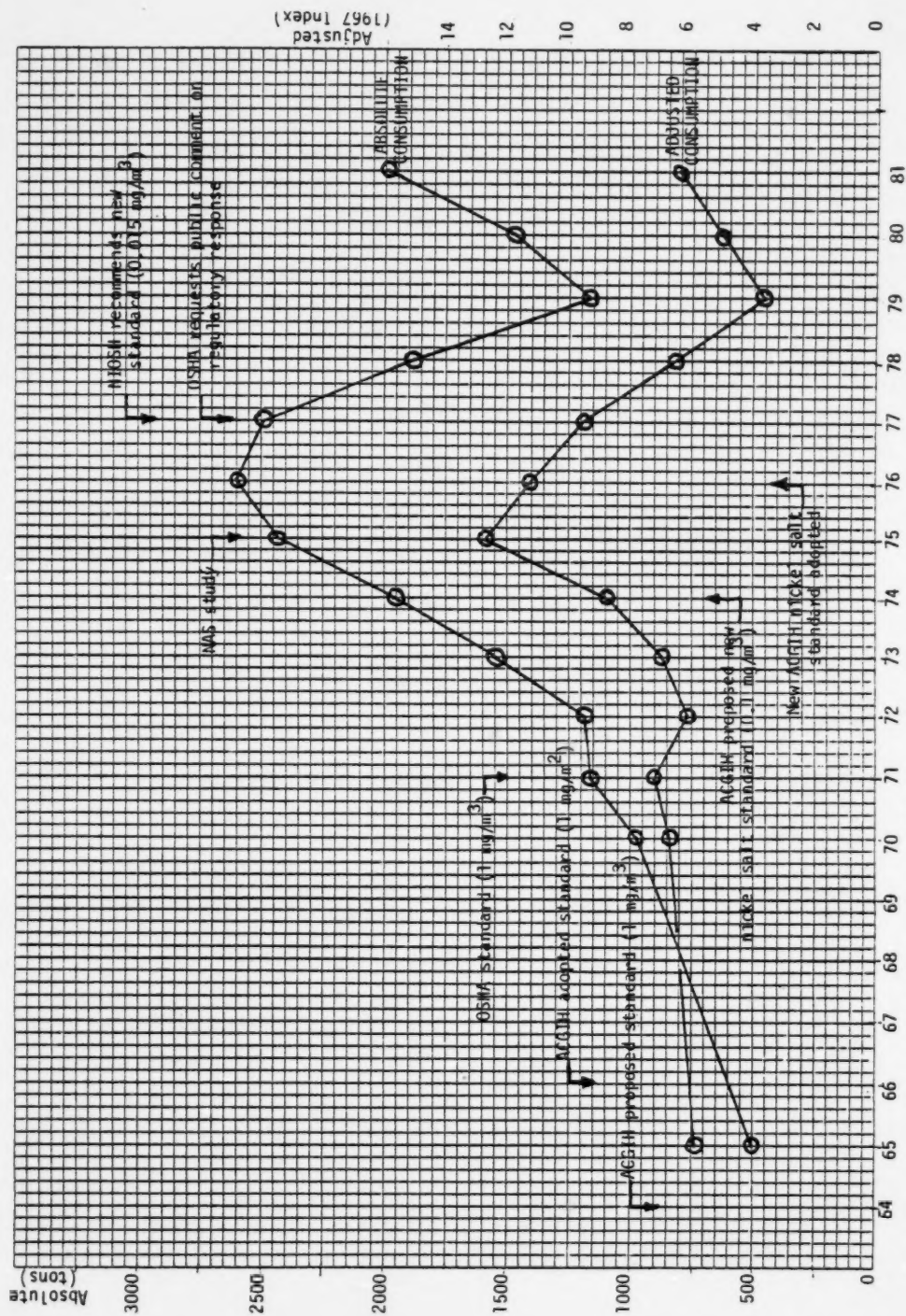
Nickel used by the chemical industry is reported in two ways: as metal alloys applied in manufacturing equipment parts exposed to corrosive chemicals (56,600 tons in 1979) used in the chemical and allied products industries and petroleum refineries (USBOM, Mineral Facts and Problems, p. 618), and as nickel consumed by the chemical industry (1,165 tons in 1979) for producing nickel compounds (Predicasts Basebook, p. 480).

As evidenced by the amounts shown for 1979 in Tables 1 and 2 above, a large difference in interpretation of chemical industry nickel consumption is possible, depending on whether one is interested in alloys or actual chemicals. This section examines the use of nickel by the chemical industry for producing nickel compounds.

Consumption of nickel for production of nickel compounds is presented in Figure 3 as both an absolute measure and as an adjusted measure consisting of the ratio of consumption to the Federal Reserve Board's Chemicals and Synthetic Materials Index (which includes inorganic chemicals). Absolute consumption steadily increased at a rate of about 191 tons per year from 1965 to 1976, then plunged 55% between 1976 and 1979 to about the 1972 level. Since 1979, it has been again increasing.

To estimate any possible regulatory impact on nickel compound production, it is useful to examine the index-adjusted curve rather than the absolute consumption curve, for this adjustment accounts for exogenous economic factors such as recessionary downturns. Two declines have been observed for the adjusted curve; one in the year 1972 (15%) and the other between 1975 and 1979 (71%). Without data on nickel compound imports and changes in industry stocks, applicable to compounds, it is not possible to assess fully other economic factors that might account for these declines. The only regulatory event which might be associated with the 1972 decline is the 1971 OSHA standard, whereas several regulatory events could be associated with the consumption downturn in 1975: the

Figure 3. Consumption of Nickel for Production of Nickel Compounds



Source: Predicasts Basebook, p. 480
Federal Reserve Board (adjusted index)

new ACGIH nickel salt standard (1974, 1976), the 1975 NAS study, and the NIOSH/OSHA actions in 1977. It is not possible to determine which of these events might have precipitated the decline, because the new, stricter ACGIH standard (0.1 mg/m^3) can be viewed as being aimed at not only producers of nickel compounds but also at nickel electroplaters, a major consumer of nickel salts (nickel chloride and nickel sulfate). On the other hand, the NIOSH/OSHA actions of 1977 did not finalize a new standard, but publicly set forth the threat of an even stricter (0.015 mg/m^3) Federal standard. Therefore, based on the data presented, it appears that both nickel consumption declines for production of nickel compounds in 1972 and 1975 through 1979 can be associated with regulatory and suspect hazard events: the 1972 decline because of the 1971 OSHA standard and the 1975-1979 downturn arising from either the proposal (1974) and implementation (1976) of a new, non-federal agency nickel standard or the pre-regulatory threat (publicly announced in 1977) of a new, proposed federal standard, or a combination of both, as well as the 1975 NAS study.

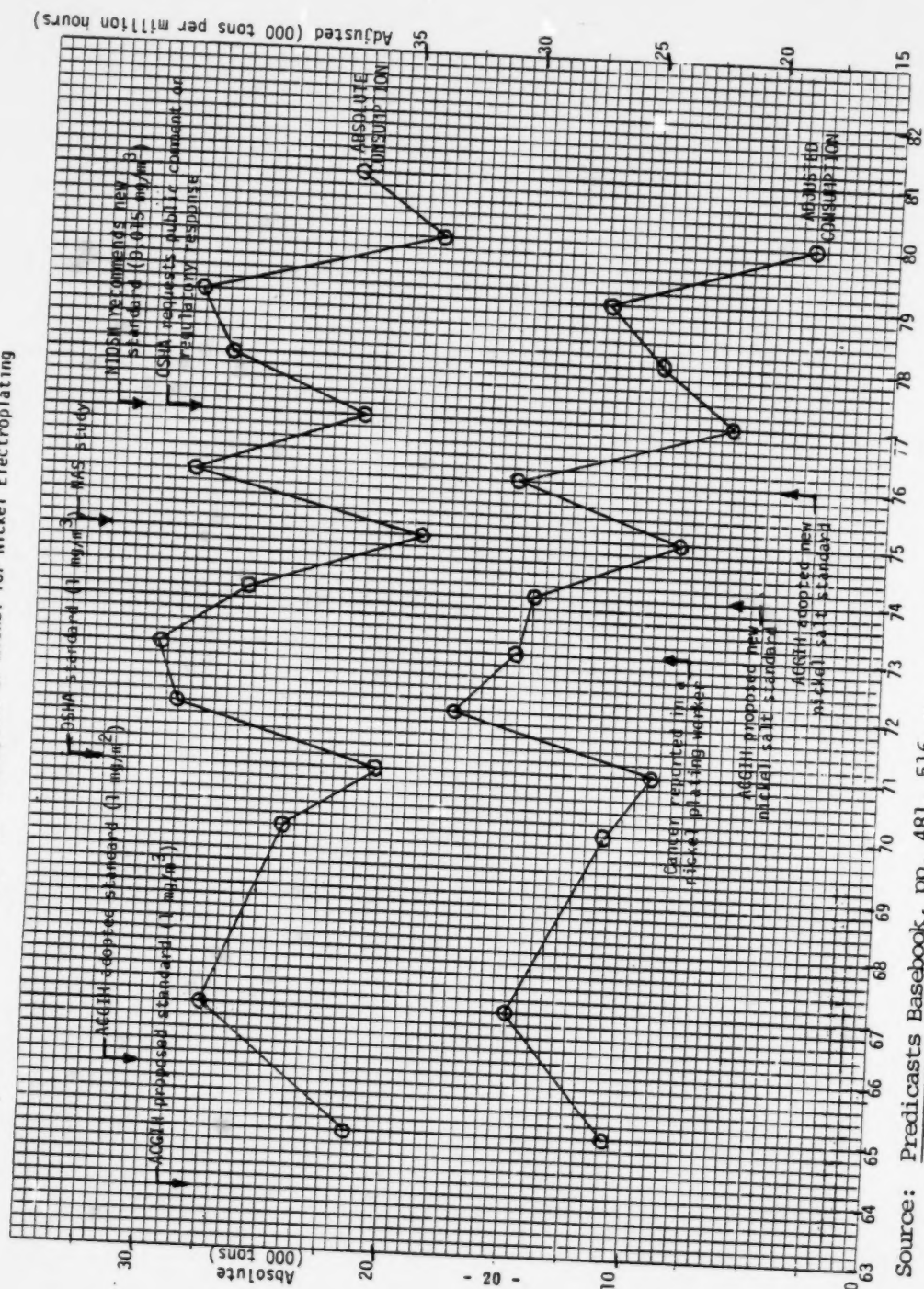
4. Nickel Electroplating

Use-specific consumption data for nickel compounds is publicly available for only one use category—nickel electroplating. Figure 4 provides both the absolute consumption of nickel used in electroplating and an adjusted measure of consumption consisting of the ratio of absolute consumption to the total hours worked in the electroplating and polishing industry.

The adjusted curve provides an indication of nickel's share in this industry and represents an adjustment to account for changes in general economic activity in electroplating operations. As shown in Figure 4, both curves fluctuate with adjusted consumption minima occurring in 1971, 1975, 1977, and 1980.

To examine for possible regulatory impact on nickel plating operations, nickel-related regulatory events are also listed in Figure 4. The generic nickel producing/consuming regulatory events are listed above the curves, while the regulatory actions which can be viewed as being aimed at the nickel plating

Figure 4. Consumption of Nickel for Nickel Electroplating



Source: Predicasts Basebook, pp. 481, 516.

industry (the 1973 report of cancer in nickel plating workers and the proposed (1974) and adopted (1976) ACGIH soluble nickel salt standards) are listed below the curves. It is interesting to note that four generic nickel regulatory events coincide with the three consumption dips in 1971, 1975, and 1977 while the nickel plating-specific regulatory events fall between these years. Whether one believes that regulatory impact has immediate consequences (e.g., same year production/consumption declines) or a lag effect (e.g., event precipitates decline in succeeding years) determines how the regulatory impact is assessed in this case.

Even though the actual nickel consumption curve has been rather constant, fluctuating around a mean value of about 25,000 tons, the index of nickel consumption to total electroplating industry hours worked has declined. This trend provides a preliminary indication that the various nickel-related regulatory events affected the behavior of nickel electroplaters. It is not possible to determine whether any one regulation carried more impact than others but it might be possible that all regulatory actions, particularly those which occurred after 1971, acted in a cumulative manner on the industry. However, further analysis is needed, for this trend might well be explained by the presence of other economic factors (e.g., changes in worker productivity, changes in waste recovery/recycling techniques). It should be noted, however, that one such factor does not appear to be an important one, i.e., changes in the relative price of substitutes. This is because the actual cost of the metal appears to be a minor factor in the total cost of plating.

F. SUMMARY

In summary, nickel and nickel compounds have been subject to a rather long history beginning as early as 1889 of occupational injury associated with their production and use in most principal categories, compounded by evidence of human carcinogenicity. Evidence of human carcinogenicity from exposure to nickel and nickel compounds has been reported in epidemiologic studies of workers in nickel refineries, nickel alloy plants, and nickel electroplating operations. Worker exposure standards were first presented in 1966 (ACGIH), and more

recently a reduced standard has been proposed by NIOSH (1977) but no yet finalized.

To assess the impact of this regulatory scrutiny, trends in the production and consumption of nickel and nickel compounds were examined together with supply factors for nickel refining, nickel alloys, nickel compounds, and nickel electroplating.

In nickel refining, occurrence of regulatory events concerning nickel seemingly had no impact. For nickel alloy production, only the 1971 OSHA standard correlated with declines in the three industry-adjusted ratios presented for nickel consumption in alloys, but potential regulatory significance could not be separated from other factors. Only in the case of nickel alloy steel did the effect of regulatory events appear separable, and in this case, the impact may have been cumulative rather than specific to any one regulatory event.

For nickel compounds, both aggregate production and use-specific consumption in nickel electroplating was examined for regulatory impact. Again, the 1971 OSHA standard was associated with a drop in nickel compound production while several regulatory events coincided with a four-year decline after 1975. For nickel electroplating, a nickel consumption series adjusted for changes in general economic activity exhibited a fluctuating but steady decline and both generic and electroplating specific regulatory events for nickel appeared to be associated with this decline.

SECTION II.9

REGULATORY IMPACT ANALYSIS FOR PERCHLOROETHYLENE (PERC)

The purpose of this summary is to report on the potential market impact of designating perchloroethylene (perc), as a suspect toxic hazard. An estimate of such impact depends upon careful examination of consumption and use characteristics, together with supply factors and regulatory history.

A. CONSUMPTION AND USE CHARACTERISTICS

Perc is a chlorinated solvent with two major uses and several secondary ones. These uses and their estimated domestic consumption (millions of pounds), based upon 1980 data are:

EXHIBIT I

DEMAND PROFILE FOR PERCHLOROETHYLENE (1980)

<u>Use</u>	<u>Millions of Pounds</u>	<u>Percent of Total</u>
Dry cleaning	308	40.3
Metal cleaning	150	19.6
Intermediate	85	11.1
Textile processing	72	9.4
Miscellaneous	110	14.4
Exports minus imports	40	5.2
<u>TOTAL</u>	<u>765</u>	<u>100</u>

Source: SRI and personal interviews with staff, International Fabricare Institute (IFI).

As the Exhibit indicates, the two major uses for which regulatory impact is potentially most significant are dry cleaning and metal cleaning. Only the dry cleaning use will be considered in this report because the metal cleaning use

category is considered in a separate report in Section II. 10 below, dealing with trichloroethylene (TCE). Other uses do not appear to be significant enough for analysis, or to provide clear data. Perc use in textile processing rose from 35-40 million pounds in 1974 to 45-50 million pounds in 1980 (SRI). Use of perc is a small factor in textile processing, however, because most processing is done by aqueous methods.

Perc is used as an intermediate primarily in the production of C₂ fluorocarbons. Consumption for this use has stayed at approximately 85 million pounds since 1974. Because fluorocarbon production itself has been characterized by regulatory uncertainty and is addressed in a separate report in this series, analysis of the economic impact of perc's regulatory situation with respect to fluorocarbon use is not considered here.

Perc has many minor uses, including use as a silicone solvent as well as in aerosol specialty products. Data were not available in sufficient detail for analysis on these less significant uses. In addition, it is not known whether inventory changes are included in this category of "miscellaneous" uses.

The last category of consumption and use, net foreign demand (exports minus imports) has grown recently (1979-80) from levels twice those of the 1974-78 period, but below those of the early 1970s. This category has not been treated in our analysis.

1. Dry Cleaning

Since the 1960s, perc has had its most significant use as a dry cleaning solvent. Because of non-flammability, high solvency, high vapor density, excellent stability, and moderate cost, it is the preferred solvent in the industry. Columns 1 and 2 of Exhibit II indicate domestic consumption and imports since 1971 of perc used in dry cleaning.

Exhibit II
Use of Perc in Dry Cleaning Operations
(mill. lbs.)

	<u>Domestic Perc Consumption</u>	<u>Imports^{1/}</u>	<u>Total Pounds of Dry Cleaning^{2/}</u>	<u>Ratio of Domestic Perc to Total Cleaning</u>	<u>Ratio of Domestic Perc + Imps. to Total Cleaning</u>
1971	330	34	1088.75		
1972	330	21	1062.5	30.3	33.4
1973	396	35	1005.6	31.1	33.0
1974	353	18	985.6	39.4	42.9
1975	331	29	890.6	35.8	37.7
1976	313	48	923.9	37.2	40.4
1977	321	46	985.0	33.9	39.0
1978	344	21	969.5	32.6	37.2
1979	348	20	1030.0	35.5	37.6
1980	308	27	1085.7	33.8	35.7
1981	341	27	1124.8	28.4	31.0
				30.3	32.7

^{1/} Import data are based on application to total imports for each year of the relative share of imports earmarked for dry cleaning use to total imports for the year 1976, based on SRI data.

^{2/} These data were obtained by applying price deflators to total receipts based on data provided by the International Fabricare Institute (IFI). The following price deflators were used. For 1980-81, revenue per pound of \$2.10; for 1978-9, \$2.00; for 1975-77, \$1.80; and for 1971-74, \$1.60.

Source: International Fabricare Institute and SRI.

Perc competes in this dry cleaning use with petroleum solvents (almost entirely consisting of one type of solvent called Stoddard Solvent) and with fluorocarbon 113 (F-113 trichlorotrifluoroethane). IFI reports that as of 1980 about 82 percent of the approximately 40,000 dry cleaners in the U.S. used perc, while 15 percent used petroleum solvent and the remainder used F-113. However, use of petroleum solvent was estimated at approximately one-half of perc by weight, for the only year which data were available (Kirk-Othmer, v. 8).

Investigation of the economic impact of suspect hazard toxicity designation requires that data on perc use be considered in relation to total dry cleaning consumption. These consumption data, as well as the ratio of total poundage of Perc to total dry cleaning poundage (with and without imports) are presented in columns 3, 4, and 5 of Exhibit II, respectively. Exhibit II indicates that beginning in 1973, there has been an average downward trend over time in the relative rate of perc use per pound of dry cleaning. This drop became even more significant in 1980-81. Data for 1982 were not available.

Investigation of economic impact also requires comparison of the relative prices of perc with its closest competitor, Stoddard solvent. Exhibit III provides such a comparison. (Comparison was not made with F-113 because IFI indicated it was not a significant market factor.) The Exhibit indicates that the price of standard solvent has been rising relative to perc for the past seven years with one exception (1979).

EXHIBIT III

Price Comparison - Perc Versus Stoddard Solvent

<u>Year</u>	<u>Price Perc</u> (cents per pound)	<u>Price Stoddard</u> (cents per pound)	<u>Stoddard/Perc</u>
1971	6.9	NA	NA
1972	5.7	NA	NA
1973	6.4	28	4.38
1974	10.5	28	2.66
1975	14.1	28	1.98
1976	14.6	63	4.32
1977	12.0	63	5.25
1978	9.8	64	6.53
1979	11.4	64	5.61
1980	15.8	110	6.96
1981	16.6	166	10.37

Source: Chemical Marketing Reporter. (Stoddard solvent prices are based on dollars per gallon for tank cars of solvent naptha at New Jersey depot, from spot quotations and/or list prices of suppliers.)

B. SUPPLY FACTORS

Perc can be produced by many processes. Some produce a single material while others produce two or more materials. In several instances, the process is flexible and can be run so as to maximize output of either co-product. Accordingly, choice of process may be based on consideration of many factors such as raw material cost, makeup of the complex in which the plant is to be a part, and extent of the fit between possible products and the producer's current line of products.

Four separate processes can be used to produce perc and/or TCE as well. A fifth produces CCl_4 in addition to perc. As of 1981, there were seven domestic producers of perc: Diamond Shamrock; Dow Chemical; DuPont; Ethyl Corp.; PPG Industries; Stauffer Chemical; and Vulcan Materials.

Significant excess perc capacity has existed for a number of years, with large capacity increments having come on board in 1978 and 1979 in anticipation of an economic expansion that never occurred. In addition, shut-down and standby capacity and significant foreign capability exist, as well as potential capacity that could shift from trichloroethylene production if needed. It is also notable that increased hydrocarbon and energy costs resulting from the energy crisis have forced production costs significantly upward over the past several years, resulting in the price increases portrayed in Exhibit III above.

C. REGULATORY HISTORY

Perc has had an interesting and varied regulatory history, including toxicity designation in the areas of workplace exposure, potential carcinogenicity, and air pollution control (maintenance of atmospheric quality). To our knowledge, no actual federal regulations have been implemented except for increases in worker exposure limits by OSHA in the early 1970s. Exhibit IV summarizes the regulatory history of perc.

EXHIBIT IV

Regulatory Actions And Events Concerning Perc

- | | |
|---------|---|
| 1970-71 | OSHA restricts worker exposure. |
| 1975 | NCI reports mice tests carcinogenic for trichloroethylene, a substantial competing solvent for metal cleaning. |
| 1976 | NIOSH criteria document recommends further reduction in permitted worker exposure level. |
| 1977 | NCI bio-assay for possible carcinogenicity of perc declared perc a potential carcinogen. |
| 1973 | In December, EPA publishes an air emissions control techniques guideline document to assist the states in developing regulations for existing perc sources. |
| 1979 | IRLG reviews regulatory status of perc; CPSC says perc may be carcinogenic. |
| 1980 | EPA proposes air quality standard for perc plants. |

D. ANALYSIS OF REGULATORY IMPACT

Our initial analysis has focused on factors associated with trends in perc use in dry cleaning and metal cleaning. Each shall be discussed in order. It must, of course, be kept in mind that this analysis is significantly limited by the small number of data points available.

1. Dry Cleaning

Perc's use in dry cleaning—as measured by the ratio of perc poundage to total dry cleaning poundage in Exhibit II—appeared to show a secular decline from a high point in 1973, when petroleum prices rose substantially thereby encouraging conversion from petroleum based solvents, until 1979. This decline was then repeated in 1980 and 1981. The decline in 1979-80 was almost as large as the entire decline from 1973 to 1979.

Two potential factors have been suggested to account for this decline: (1) a possible shift in the price of perc relative to Stoddard solvent, its major competitor for dry cleaning use; and (2) the possible impact of suspect hazard toxicity designation by one or more of the following—NCI, NIOSH, EPA, CPSC, IRLG, and OSHA—as well as actual and/or proposed state and federal hazardous waste and pollution emissions control regulations. Each factor shall be discussed in order.

a. Relative Prices

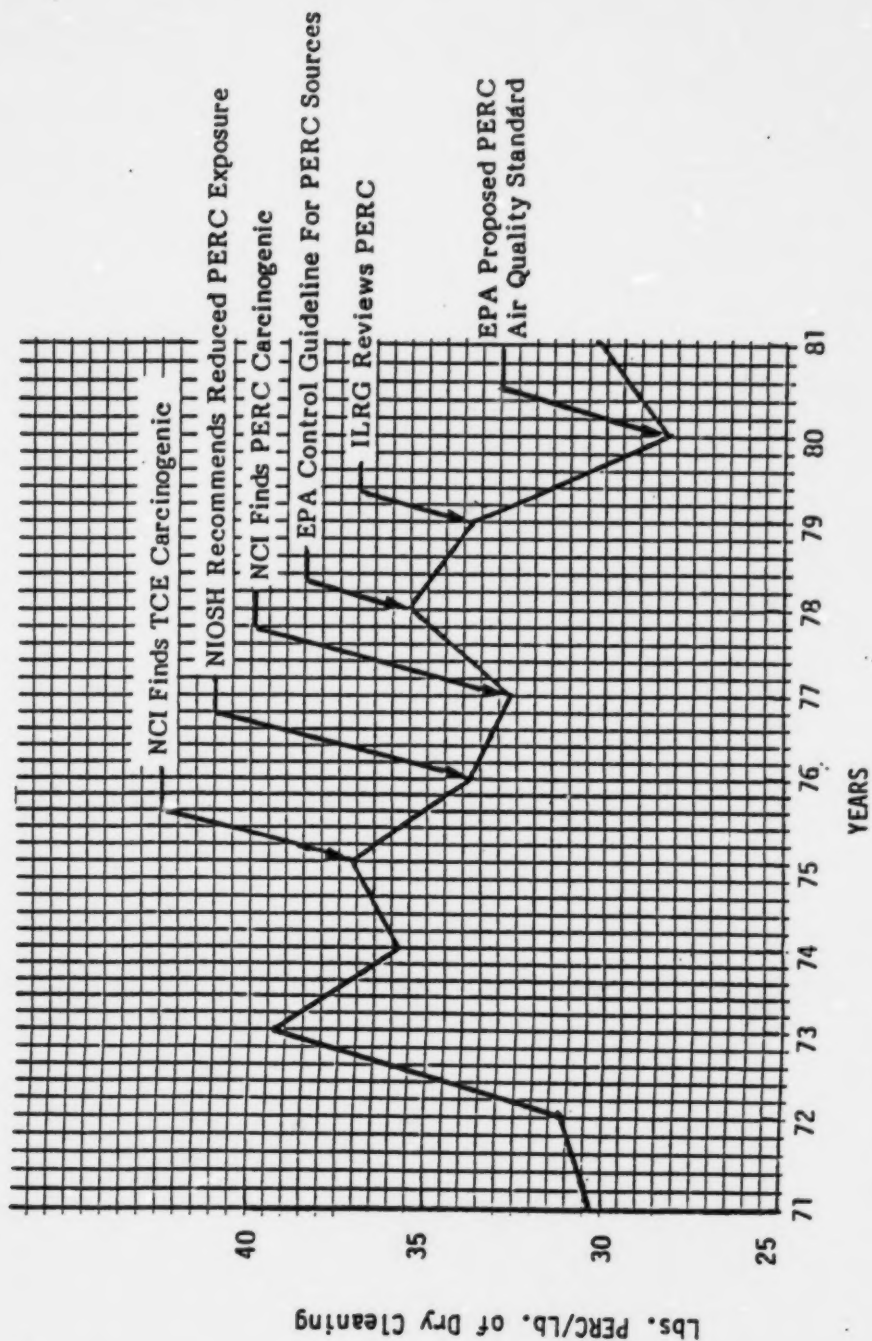
If relative price differences are to explain the decline in relative perc use, this reduction should be associated with an increase in the relative price for perc. As Exhibit III indicates, however, this is simply not the case. In fact, contrary to economic logic, quite the opposite is true. A decrease in the perc input ratio to dry cleaning poundage occurs despite perc's increasing price advantage relative to its nearest competitor. The causes of perc's trend in dry cleaning use appears to lie elsewhere than in relative price trends.

b. Toxicity Designation and Regulatory Factors

The trend downward in the ratio of perc use to total dry cleaning poundage appears on its face to be significantly associated with regulatory events. Exhibit V indicates graphically the trend downward over time in intensity of perc use, compared with the timing of regulatory events. There was a notable decline in average use for 1980-81 over previous years, immediately after the IRLG and CPSC actions and just prior to the time that EPA's stationary source emissions control proposal was announced. A significant drop from the previous year was also recorded in 1976, when NIOSH recommended a reduction of perc worker exposure levels, and in 1977—the year of the NCI carcinogen bioassay. An increase in the perc-use ratio occurred in 1978—a year that was free of new regulatory events until December, at which time EPA published emissions control guidelines. Two regulatory events in 1979—by IRLG and CPSC—brought a further decline from the previous year.

EXHIBIT V

QUANTITY OF PERC USED AS DRY CLEANING SOLVENT FOR THE YEARS 1971-1981



Source: Exhibit II.

While these data are by no means dispositive of the question of impact of toxicity announcements or intention to regulate, they are suggestive that such impact exists. It would occur in one or both of two ways: (1) an increase in plant conversion behavior by dry cleaners in order to comply with state or proposed federal pollution guidelines or regulations for stationary source emissions. Conversion serves to increase the perc recovery rate and thus lower the proportion of perc used; and (2) a switch to competitive solvents, in this case primarily Stoddard solvent. More precise estimation of regulatory impact on perc use in dry cleaning requires that these two influences be separated since the declining ratio of perc use may be in significant measure the result of actual pollution control regulation in the states rather than a toxicity designation or proposal to regulate.

E. SUMMARY

The impact of suspect hazard designation and regulatory events on use of perc was studied on a pilot basis for one major use category; dry cleaning.

Our preliminary analysis showed that time trends in perc use in dry cleaning tended to be correlated with a series of toxic designation events beginning in 1975. It was also found that relative prices of perc and competing solvents not only do not explain usage trends, but go in the opposite direction as an explanatory variable. Further investigation is needed of the extent to which increased recovery of perc as a result of compliance with proposed EPA emission guidelines may also be contributing to the downward trend in perc use.

Where toxic regulatory events for two chemicals appeared to be approximately similar, one would expect usage to depend to a greater extent on price. Where regulatory events were dissimilar, one would expect usage to be less highly correlated with price. These expectations were initially confirmed. While additional research must be conducted as to other possible explanatory factors, initial results for this chemical appear promising.

SECTION II.10

REGULATORY IMPACT ANALYSIS FOR TRICHLOROETHYLENE (TCE)

The purpose of this summary is to report on the potential market impact of designating TCE as a suspect toxic hazard. An estimate of such impact depends upon careful examination of consumption and use characteristics together with supply factors and regulatory history.

A. CONSUMPTION AND USE CHARACTERISTICS

About 80% of TCE is consumed in vapor degreasing of fabricated metal parts; the remaining 20% is divided equally between exports and miscellaneous applications (Kirk-Othmer, v. 5). Miscellaneous applications are: as a dry-cleaning solvent; as an extractive solvent for coffee, oil seeds, spices, and other foods; and as a component of certain drugs. It is also used as a component in adhesive and paint-stripping formulations, a low-temperature heat-transfer medium, a nonflammable solvent carrier in industrial paint systems, a solvent base for metal phosphatizing systems, and as a solvent in waterless preparation, dyeing, and finishing operations.

The focus of this analysis will be on TCE's major use as a solvent in degreasing of metal surfaces. Solvent cleaning operations are of three major types: cold cleaning, open-top vapor degreasing, and conveyerized (cold and vapor) degreasing. TCE is principally used in vapor cleaning operations, which accounted for about 84% of TCE use in 1974 and 95% in 1975.

Exhibit I shows metal cleaning and other (miscellaneous) uses of TCE for five selected years. As the Exhibit shows, TCE's importance as a solvent for metal cleaning has been declining significantly over the past ten years. In 1971, it accounted for 55% of all chlorinated solvents used in vapor degreasing. By 1976, it's share had declined to 42% and by 1980 to less than 24%. Major competitors of TCE are 1,1,1-TCE and perchloroethylene (perc). However, several other solvents

EXHIBIT I

ESTIMATED U.S. CONSUMPTION OF TCE BY END USE (millions of pounds)

	<u>Metal Cleaning</u>	<u>Miscellaneous</u>
1971	440	32
1974	337	9
1975	252-263	4-15
1977	225	45
1980	190	24

Source: SRI.

are competitive for certain types of degreasing operations. Exhibit II shows consumption of TCE and all competing solvents for each of the three major degreasing processes for 1974, the only year for which complete data were available on a process-by-process basis.

Exhibit III shows consumption trend and price data of TCE and two other major solvents, (1,1,1-Trichloroethane (1,1,1-TCE) and perc), for the five years for which data are available.

B. SUPPLY FACTORS

TCE is produced by several processes. It is produced as a joint product with perc through any of the following processes: (1) chlorination of C₂ chlorinated hydrocarbons, (2) oxychlorination of C₂ chlorinated hydrocarbons, (3) chlorination

EXHIBIT II

ESTIMATED NATIONAL DEGREASING SOLVENT CONSUMPTION (1974) (Millions of Pounds)

Solvent Type	Cold Cleaning	Vapor Degreasing	Convey- orized	Total	
	<u>1974</u>	<u>1974</u>	<u>1974</u>	<u>1974</u>	<u>1975</u>
Halogenated:					
Trichloroethylene (TCE)	112	150	75	337	344-370
1,1,1 Trichloroethane (1,1,1-TCE)	119	159	79	357	252-263
Perchloroethylene (PERC)	40	53	26	119	108
Methylene Chloride	22	29	15	66	19-70
Trichlorotrifluoroethane	22	29	15	66	66
Aliphatics	489				
Aromatics:					
Benzene	15			15	
Toluene	31			31	
Xylene	26			26	
Cyclohexane	2			2	
Heavy Aromatics	26			26	
Oxygenated:	64				
Ketones:					
Acetone	22			22	
Methyl Ethyl Ketone	18			18	
Alcohols:					
Butyl	11			11	
Ethers	13			13	

Source: EPA contractor reports 6/76 and 7/78.

EXHIBIT III

SELECTED PRICE AND PRODUCTION DATA FOR TCE AND MAJOR COMPETITORS IN METAL CLEANING

(consumption in millions of pounds; price in cents per pound)

	<u>TCE Consumption</u>	<u>Price</u>	<u>1,1,-TCE Consumption</u>	<u>Price</u>	<u>PERC Consumption</u>	<u>Price</u>
1971	440	6.8	250	9.5	110	6.9
1974	337	11.5	357	13.0	119	10.5
1975	252-263	15.2	320	16.8	108	14.1
1977	225	15.9	390	20.4	130	12.0
1980	190	19.6	440	24.1	150	15.8

Source: SRI, p. 632.3001L (consumption data)

U.S. International Trade Commission (price date)

of ethylene and thermal dehydrochlorination of product, and (4) chlorination of acetylene. As of 1981, there were three major producers of TCE: Dow Chemical Co. — TX, Ethyl Corp. — LA, and PPG Industries, Inc. — LA.

The decline in TCE consumption and use was met by a series of plant shutdowns in the early 1970s. No new production capacity has been planned for some time. Based on 1971 production of 270 million pounds, compared with capacity of 365 million pounds, excess capacity appears to characterize the industry. Thus, there did not appear to be any significant supply constraints.

C. REGULATORY HISTORY

TCE has a long and significant regulatory history for its metal cleaning use which can be divided into three time periods.

The first time period, 1966-1974, was a period of increasing regulation of TCE for its contribution to air pollution. In 1966, the Los Angeles Air Pollution Control Board (LAAPCB) designated TCE as a photochemically reactive solvent that decomposed in the lower atmosphere, contributing to air pollution. Many degreasers met the requirements by switching from TCE to competing degreasing solvents. In 1970, all states were required to submit pollution control plans to EPA to meet national air quality standards. States were given until May 31, 1975 to comply, but extensions of up to two years were granted. Spurred by the federal schedule, many states followed the California example and restricted TCE emissions.

The second time period consisted of a single year, 1975. This was the year of regulatory designation of TCE as a potential carcinogen. In 1975, a stricter standard for worker exposure to TCE vapor was proposed by OSHA, acting on a series of NIOSH health studies published in the previous year. (OSHA proposed a maximum allowable exposure level of 100 ppm on an eight-hour time-weighted average basis). In this same year, TCE was designated as a carcinogen in mice. EPA issued a memorandum of alert regarding its use in the presence of humans.

Also in this year, EPA proposed interim drinking water regulations requiring specific treatment systems to deal with TCE contamination. The LAAPCB also tightened its photochemical emission rules regarding TCE in this year.

The third time period, also a single year, 1980, was another period of potential regulatory designation, this time with two events occurring. After a preliminary (1978) assessment by its Clean Air Group, the EPA Air Quality Office issued a proposed federal standard to specifically limit TCE emissions in metal cleaning use. The proposed standard specified several equipment designs and work place practices for controlling emissions. Also in this year, an Inter-agency Regulatory Liaison Group (IRLG) task force was constituted to study an overall regulatory strategy for TCE and to coordinate inter-agency interests in this chemical.

In addition, for the minor miscellaneous uses there was significant regulatory interest by the Food and Drug Administration (FDA) as well, all concentrated in 1970-79. FDA proposed new regulations and put others into effect as follows:

- In late 1977, proposed prohibition on the use of TCE as a food additive, both directly or indirectly. The proposal applied to hop extraction, decaffeination of coffee, isolation of spice oleoresins, and other applications. In the same series of actions, it proposed banning of TCE use in drugs, anesthetics, cosmetics, animal drug products, and detergents.
- In 1978, final rule to delete TCE from the list of permissible solvents in certain color additives, and to amend the food additive regulations, to delete provisions for use of TCE in the manufacture of food and food contact surfaces.
- In 1979, proposed regulation declaring that any human or animal drug product containing TCE was a new drug and, therefore, misbranded. Also, declared pet food containing TCE to be adulterated.

D. ANALYSIS OF REGULATORY IMPACT

Exhibit IV shows the relation between overall TCE consumption for metal degreasing and the regulatory events discussed above.

Data show two major declines in TCE consumption that occurred at approximately the same time as a potential regulatory designation.

- A 23-25% reduction between 1974 and 1975 at the time of the proposed OSHA standard and designation as a potential carcinogen.
- A 25% reduction between 1979 and 1980 at the time that EPA proposed its new metal cleaning standard, and the IRLG expressed renewed interest.

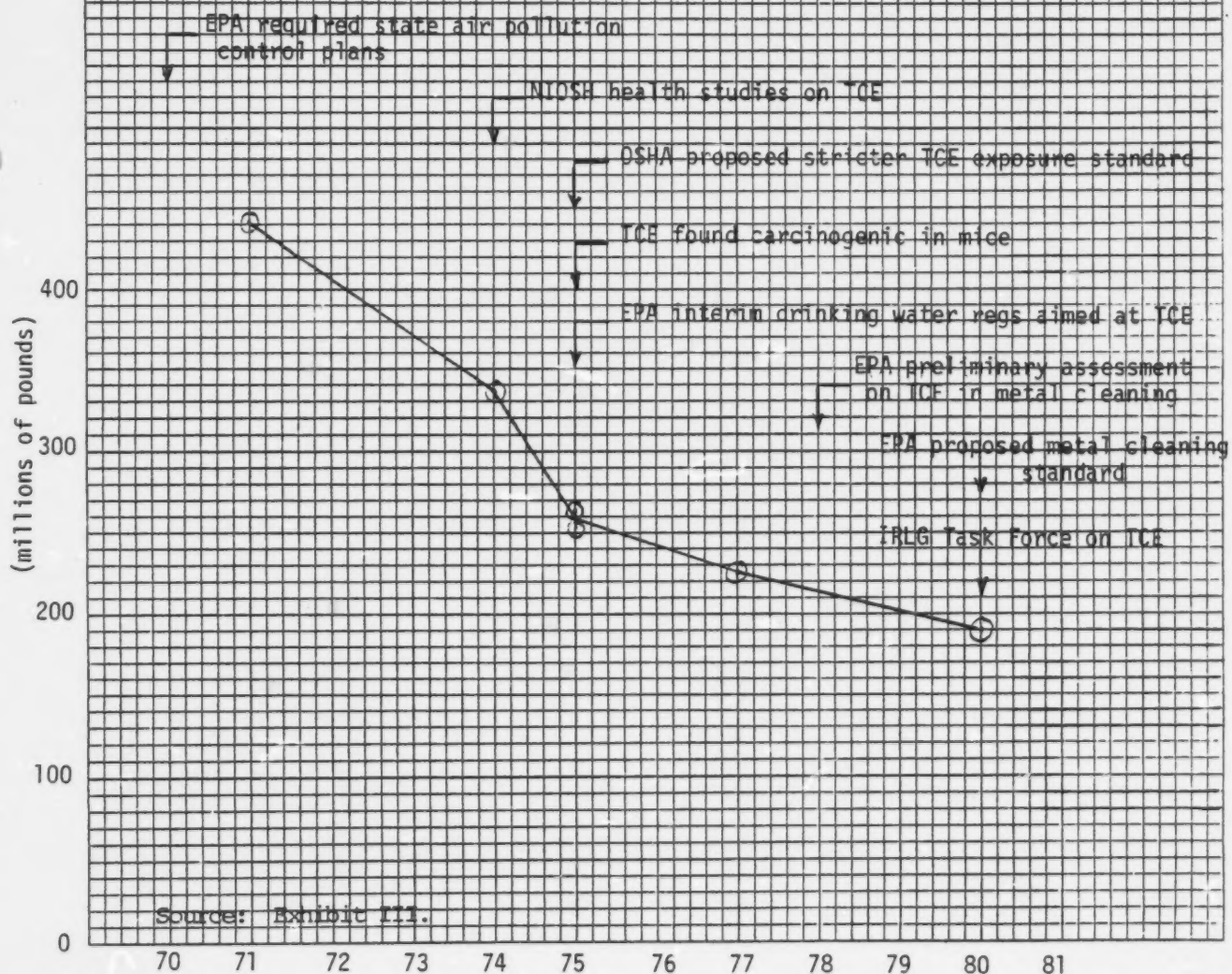
To determine the actual effect, if any, of regulatory designation on this decline, other factors potentially contributing to the decline must be examined and separated from the regulatory designation factor. These include:

- Changes in the overall level of metal degreasing activity
- Changes in relative price
- Impact of actual regulatory compliance, in this case state-by-state compliance with emissions implementation schedules affecting metal degreasers.

Each of these shall be discussed in order.

EXHIBIT IV

TCE Consumption in Metal Degreasing and Regulatory Milestones



Source: Exhibit III.

1. Changes in Level of Activity:

The years 1974-75 and 1979-80 were both periods of decline in overall economic activity in industries that degrease metals. Exhibit V shows for each of the eight industry categories where metal degreasing takes place*, the level of overall economic activity between 1974-75 and 1979-80 (based on total production worker hours), as well as the estimated percentage of firms in each of the eight industry categories that primarily use metal cleaning solvents (based on 1975 survey data provided by EPA). By weighting the rates of change in activity in each of the eight industries by the number of hours worked (corrected by the percentage of firms using metal cleaning), an overall rate of change in metal cleaning activity can be approximated. Results showed a decline of 13% in overall activity between 1974-75 and 8% between 1979-80.

Thus, a significant part (13 percentage points) of the 25 point decline in TCE use in 1974-75 appears to be associated with the general decline in economic activity in the metal cleaning sector. Applying the same procedure to 1979-80, approximately 8 percentage points of the 25 point total decline in activity occurred.

* Source: U.S. Environmental Protection Agency, Control of Volatile Organic Emissions from Solvent Metal Cleaning, (OAQPS No. 1.2-079), EPA-450/2-77-022, November, 1977, p. 2-2. Examples of industries within these classifications are automotive, electronics, appliances, furniture, jewelry, plumbing, aircraft, refrigeration, business machinery and fasteners. All are frequent users of organic solvents for metal cleaning. It should be noted that, though these industries are considered to be the most frequent sources of metal degreasing activity, use is not limited to them. Solvent metal cleaning is also used in non-metal working industries such as printing, chemicals, plastics, rubber, textiles, glass, paper and electric power. Often, the function of the organic solvents in these industries is to provide maintenance cleaning of electric motors, fork lift trucks, printing presses, etc. Even in non-manufacturing industries, solvent metal cleaning is commonplace. Most automotive, railroad, bus, aircraft, truck and electric tool repair stations use these solvents. In short, most businesses perform solvent metal cleaning, at least part time, if not regularly.

EXHIBIT V

HOURS OF PRODUCTION WORKERS (millions)

Industry Category	% Metal Cleaning	1974	1975	% Change 1974-5	1979	1980	% Change 1979-80
25	71	732	611	16.5	769	727	11.71
33	58	1,995	1,638	17.9	1,887	1,638	10.38
34	73	2,415	2,091	13.4	2,538	2,381	8.44
35	66	3,024	2,661	12.0	3,266	3,149	7.92
36	69	2,389	1,946	18.5	2,588	2,492	12.77
37	70	2,469	2,217	10.2	2,758	2,371	7.14
38	71	653	590	9.6	722	721	6.82
39	61	636	566	11.0	641	603	6.71

Source: Annual Survey of Manufacturers

Table 1. General Statistics for Industry Groups and Industries: 1975 and 1974,

Table 2. Statistics for Industry Groups and Industries: 1980 and 1979.

2. Changes in Relative Price

Some of the reduced production and use of TCE in metal degreasing could be potentially due to the lower price of substitutes. Exhibit VI shows the relative price and consumption of TCE and two major competitors, for the years 1971-80.

EXHIBIT VI

RELATIVE PRICE AND CONSUMPTION OF TCE SUBSTITUTES

	Relative Price		Relative Consumption	
	<u>1,1,1-TCE</u> <u>TCE</u>	<u>Perc</u> <u>TCE</u>	<u>1,1,1-TCE</u> <u>TCE</u>	<u>Perc</u> <u>TCE</u>
1971	1.40	1.01	0.57	0.25
1974	1.13	0.91	1.06	0.35
1975	1.10	0.93	1.24	0.42
1977	1.28	0.75	1.73	0.58
1980	1.23	0.81	2.32	0.79

Source: Exhibit III.

Data show that the major competitor, 1,1,1-TCE, became slightly (3%) less expensive than TCE in 1975, while a secondary competitor, perc became slightly more expensive (2%). These changes, particularly since they are offsetting, would not appear to be sufficient to have caused a significant drop in TCE output. A regression fit of relative consumption on relative price applied to 1975 data shows a predicted drop of only 1% in TCE consumption as a result of a 2% fall in 1,1,1-TCE's price; while the relative price rise in perc leads to an offsetting gain for TCE of 0.5%.

Likewise, for 1980, 1,1,1-TCE became somewhat less expensive relative to TCE once again (this time by 8.2%), while again perc rose in relative price, this time by a substantial 26%. The regression fit of relative consumption on relative price applied to these 1980 data shows a net drop of 1.2% in TCE consumption as a result of these relative price differences.

In summary, for both 1974-75 and 1979-80 relative price changes do not explain a substantial amount of the observed drop in TCE consumption.

3. Impact of Regulatory Compliance

Some of the decline in the use of TCE observed in the 1975 period could be potentially due to a continuing substitution of other solvents for TCE in order to reduce emissions in compliance with State Implementation Plans (SIPs). Although control technology was available to reduce hydrocarbon emissions from existing solvent metal cleaning operations by the 70s, it was generally not used. Rather, implementation plans generally followed those of the LAAPCB. Generally, up to 3,000 pounds of volatile organic compound emissions per day were allowed from sources using solvents considered non-photochemically reactive under the LAAPCB. Since solvent metal cleaning operations rarely release more than that amount, they have usually complied with LAAPCB regulations merely by substitutions of some other chemical for TCE.

Analysis of the timing of SIPs, however, shows that by the end of 1974, their impact on TCE substitution may have been largely felt, and that adoption of SIPs by new states in 1975 and thereafter did not significantly increase substitution of other chemicals for TCE after the year 1974.

The basis for this finding is our analysis of EPA contractor data referenced above which shows that by the end of 1974, 18 states having an estimated 65% of total employees in large establishments (20 employees or more) in the 8 major industries classified as performing metal cleaning, were fully implementing the regulations (most of these were implementing the regulations by early

1974). An additional 6 states having 15% of total employees in large establishments, fell into the category of states which would not be expected to discontinue TCE use as a result of Clean Air Act (CAA) implementation*.

Thus, by the end of 1974, an estimated 80% of employees were in states that had implemented their pollution control plans in ways that had already affected switching from TCE, if the establishment was to be affected at all. Only two additional states, Colorado and Texas with 1.4% of employees in large establishments, came into compliance in 1975. The remaining states complied after 1976.

Potential additional switching from TCE in 1975 and 1980 as a result of the tightening of the existing LAAPCB regulations in these years was also examined. This tightening was not estimated to have significant additional switching impact, since EPA indicated in its contractor report that additional significant pollution reduction after 1974 could only be achieved by technological modifications, rather than simple switching to less polluting chemicals. Moreover, the major opportunities for switching in California had already occurred by 1975.

It should be noted that conclusions as to the impact of actual regulatory compliance on TCE use is based solely on preliminary examination and analysis of public census data, as well as other referenced materials. The simplifying assumption that the rate of substitution of competing chemicals for TCE would be the same for all states having SIPs, and for all of the 8 major user industries in these states was used. A detailed compliance study would be needed to identify substitution behavior more precisely, but was not practical in this preliminary study.

No other significant explanatory factors, such as supply constraints during the relevant period, were found to exist.

* This included Michigan as the major user, and other midwestern states.

E. SUMMARY

Based on the above analysis, it appears that the significant consumption and production declines for TCE observed in 1975 and 1980 can be diagnosed as follows.

Of the 23-25% decline in the production and use of TCE in metal degreasing between 1974-1975,

- Approximately 13 percentage points of the decline were associated with a general decline in economic activity in user industries.
- Approximately 1.5 percentage points were associated with adoption by Colorado and Texas of implementation plans patterned on the L.A. model (assuming that the rate of switching remained the same as for firms and states already having plans).
- Approximately 1 percentage point was due to price increases of TCE relative to competing products.

Thus, approximately 10 percentage points of falling production and consumption does not appear to be explained by economic factors or regulatory compliance. In the absence of other explanatory factors, it is, therefore, hypothesized that the regulatory announcement of the proposed OSHA standard in 1975, coupled with the mice carcinogen finding in that same year, affected TCE production and use by approximately 10 percentage points.

Of the 25% decline in the production and use of TCE in metal degreasing between 1979-80,

- Approximately 8 percentage points were associated with the decline in economic activity.
- Approximately 2 percentage points were due to relative price changes.

- No change was due to incremental regulatory compliance.

Thus, approximately 16 percentage points of falling production and consumption does not appear to be explained by economic factors or regulatory compliance. In the absence of other explanatory factors, it is, therefore, hypothesized that proposal of the federal standard to limit TCE emissions in metal cleaning use, together with the IRLG task group formation, affected TCE production and use by approximately 16 percentage points.

III. ECONOMETRIC ANALYSIS

In this section, we report on our preliminary efforts to develop a formal econometric modeling framework for examining in a more rigorous quantitative manner the impact of suspect hazard designation on the use and activity categories for the chemicals which have been examined. First, a formal econometric regression model is developed for each applicable use and activity relevant to the ten chemicals examined above. Next, data available for 25 uses and activities relevant to these ten chemicals are pooled in a set of cross-section time-series regression models, in order to assess the impact of suspect hazard designation in overall aggregate terms. Finally, this aggregate econometric analysis is extended to include eight new chemical uses or activities involving four additional chemicals, for a total of 33 chemical uses and activities.

A. INDIVIDUAL STATISTICAL MODELLING FOR TEN CHEMICALS AND 25 APPLICABLE CHEMICAL USES/ACTIVITIES

The statistical model developed for 25 individual chemical cases assumes that production or use depends not only upon the pre-regulatory and regulatory events hypothesized, but also depends upon economic variables as well. Four types of independent explanatory variables were assumed to be relevant:

- Demand Variables. These consist of: (1) the relative price of substitutes. As the price of chemicals which can be used or supplied as substitutes rises or falls relative to the chemical being studied, output of the studied chemical should rise or fall respectively; (2) level of general economic activity. As the general economy expands or contracts through economic recovery or recession, the consumption or production of individual chemicals will be affected as well, since most are used in products which vary with the business cycle.
- Supply Variables. These consist of individual resource factors or inputs used for production for the chemical in question, as well as production constraints or new production-enhancing technological factors. For example, nickel electroplating operations in the 1970s appear to have been characterized by substantial changes in waste recovery/recycling techniques, which must be considered in estimating the impact of suspect hazard designation.

- Suspect Hazard Designation. All else equal, designation of a chemical as a suspect hazard, whether through an academic study, expression of agency interest or other event, can be hypothesized to have a significant negative impact on consumption or production for the use in question.
- Actual Regulation. All else equal, the act of regulating production or use of a chemical should have a significant impact on its consumption or production.

To assess the impact of suspect hazard designation, consumption or production of a chemical must be adjusted to reflect the overall potential for its supply or use. For example, arsenic used as a herbicide on cotton must be deflated by a "user" index of cotton production to compensate for the fact that an observed decline may result not from a regulatory event, but rather from a decline in actual cotton production. Likewise, a study of suspect hazard designation on levels of cadmium production must be adjusted for changes in levels of competing products—in this case, imports. While such an adjustment factor or variable could be treated as a separate independent variable in a modeling equation, it is here treated as a denominator used to deflate the levels of consumption or production that serve as the dependent variable for each of the 25 chemical cases under study.

The most general form of the model can be specified by the following estimation equation for each chemical:

$$\frac{Y_{ij}}{U_{ij}} = K + C_1 PR_{ij} + C_2 R_{ij} + C_3 X_{1ij} + C_4 X_{2ij} + C_5 X_{3ij}$$

Where:

- PR and R stand for pre-regulatory (suspect hazard designation) and regulatory events, respectively.
- C_{1-5} are the regression coefficients for estimation.
- j is the number of important PR or R events, and is specific to each chemical use or operation, ranging from 1 to 4 for the PR variable and 1 to 3 for the R variable.

- i represents the year of each observation.
- X_1 represents an index of the level of overall economic activity.
- X_2 represents an index of supply (chemical feedstock) or resource constraints.
- X_3 represents an index of the price of the chemical relative to the price of substitutes for the use/operation in question.
- Y is the dependent variable and represents level of consumption or production of the chemical.
- U_i represents the "overall potential" deflator for Y and is specific to each of the 25 uses or operations studied.
- K represents the intercept constant.

For testing purposes:

- PR_{ij} and R_{ij} were treated as dummy variables, and assigned a value of one for the year i in and after which the respective pre-regulatory or regulatory events occurred and zero for previous years.
- Each PR and R from 1 through j was estimated in its own separate modeling equation, rather than in a single equation. This was done because for most chemicals, the number of observations was limited, thus preventing consideration of all PR and R variables simultaneously.
- A standard assumption of this type of analysis was used, i.e., that a linear relationship existed between the dependent and independent variables, specifically between a given percentage change in each category of economic activity and the percentage change observed in individual use or operations of the chemical in question. Based on this assumption, logarithms (natural) were used as a measure of Y_i , U_i , and all X_i .

Data used to estimate the model for each variable were obtained almost entirely from public sources as a result of our specific research on each chemical substance. Source data for each variable are discussed and/or presented in the ten individual reports in the previous chapter and are summarized in Appendix A for each of the 25 uses or operations considered. Three important points should be noted:

- For the economic activity variable X_1 , one of two general chemical indices were used depending upon the type of chemical: the Index of Chemical and Synthetic Materials (CSM) or the Index of Chemical and Allied Products (CAP). Source for the indices was the Federal Reserve Board (See Appendix A for individual chemical designation).
- The supply variable X_2 , was estimated for each of the 25 chemicals through use of production or consumption series for the major feedstock to each chemical. Usually, the sum of domestic production plus imports, plus changes in industry and/or government inventories of the chemical substance was used to indicate aggregate supply (See Appendix A for individual chemical designation).
- Given the limited number of observations in the time series studied, a maximum of four major pre-regulatory and three regulatory events were selected for analysis. In some cases this represented a judgment call as to what constituted a major event.

It should be noted that where price data (X_3) were not available (18 of 25 cases), the model was estimated without this variable. This omission did not seriously hamper our analysis, however, because in most cases of unavailability, industry experts or other publicly available sources had indicated that price and availability of substitute products were not significant factors explaining user or producer behavior.

The model as described above was then estimated for each of the 25 chemical uses or operations, using standard co-variance and least squares dummy variable procedures.¹ The results for each use or operation are summarized in Exhibit I. Included are parameter or coefficient estimates for each variable,

¹ Discussion of this and other possible modeling approaches mentioned in this chapter is contained in several sources. One convenient recent source is Terry E. Dielman, "Pooled Cross-Sectional and Time Series Data: A Survey of Current Statistical Methodology," The American Statistician, May 1983, Vol. 37, No. 2, pp 111-122.

EXHIBIT I

ESTIMATE OF PERCENTAGE CHANGES IN ADJUSTED OUTPUT/CONSUMPTION
RESULTING FROM SUSPECT HAZARD DESIGNATION
FOR 25 CHEMICAL SUBSTANCE CATEGORIES

Chemical Substance Category	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation		Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				Pre-Regulation (Suspect Hazard)				Regulation				
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂			
CADMIUM												
Refining	0.70/ 0.84	4.07/ 9.25	7	-0.51 (-2.50)*	-0.31 (-0.98)	-	-	-0.50 (-2.18)*	-0.01 (-0.02)	-1.35/ -0.44 (-2.33/ -0.92)	0.67/ 1.39 (0.82/ 2.07)	-1.08/ 0.11 (2.07/ 0.17)
	0.88	14.37	6	-0.40 (-3.18)*	-	-	-	-	-	-0.15 (-0.40)	0.04 (0.11)	-
Plating	0.72/ 0.78	6.13/ 8.37	7	-0.09 (-0.59)	-0.22 (-1.38)	-0.03 (-0.19)	-0.16 (-0.87)	0.05 (0.34)	0.15 (0.91)	-0.62/ -0.03 (-2.16/ -0.09)	1.91/ 2.52 (3.47/ 4.26)	-
DYES												
Benzidine	0.86/ 0.88	10.55/ 12.48	5	-0.47 (0.27)	-	-	-	-0.93 (-0.94)	-	-16.67/ -13.98 (-3.71/ -3.13)	0.66/ 1.03 (0.42/ 0.47)	-
	0.79/ 0.97	5.00/ 43.42	4	-0.83 (-1.15)	-0.11 (-0.24)	0.66 (0.80)	-1.82* (-4.93)	0.04 (0.09)	-	-4.54/ -0.46 (-2.68/ -0.18)	-2.06/ -0.20 (-2.19/ -0.54)	-
Direct Black 38	0.80/ 0.87	8.01/ 13.87	6	-0.64 (-0.65)	-0.25 (-0.41)	-0.96 (-1.17)	-	-0.09 (-0.15)	-0.95 (-1.88)	-4.25/ -2.14 (-1.77/ -0.78)	-1.79/ -0.97 (-1.47/ -1.07)	-

Chemical Substance Category	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation		Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂			
Direct Brown 95	0.85/ 0.95	11.68/ 35.89	6	0.34 (0.63)	-1.64* (-3.42)	-	-	0.43 (0.79)	-0.78 (-1.60)	-5.52/ -0.77 (-2.59/ -0.48)	-1.35/ -0.84 (-1.83/ -1.49)	-
Home (Consumer) Dyes	0.96	7.63	1	-0.50 (-2.73)	-	-	-	-	-	8.60 (3.27)	-1.42 (-3.18)	-
<u>CHROMIUM</u>												
Pigments	0.45/ 0.54	3.05/ 4.29	11	0.04 (0.60)	0.03 (0.52)	-0.08 (-1.44)	-	0.01 (0.17)	-	0.04/ 0.16 (0.23/ 2.09)	0.39/ 0.44 (2.09/ 2.99)	-
Metal Treatment	0.39/ 0.51	1.46/ 2.42	7	-0.07 (-0.89)	0.01 (0.15)	-0.05 (-0.43)	0.02 (-0.22)	-0.03 (-0.34)	0.09 (1.34)	-0.07/ 0.13 (-0.56/ 0.70)	-0.36/ -0.23 (-1.62/ -0.72)	-
Leather Tanning	0.61/ 0.81	6.33/ 17.50	12	0.21* (2.19)	0.26* (3.50)	0.28* (4.28)	-	-0.18 (-1.60)	-	0.002/ 0.54 (0.01/ 3.37)	-0.16/ 0.51 (-0.70/ 2.58)	-
<u>TCR</u>												
Metal Degreasing	0.98/ 0.98	27.19/ 74.83	5	-0.19* (-2.00)	-0.24* (-3.51)	-0.12 (-1.21)	-	-	-	-2.10/ -0.57 (-3.29/ -0.94)	-0.59/ 0.72 (-1.06/ 1.05)	-0.28/ 0.37 (-0.78/ 0.89)

Chemical Substance Category	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation		Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂			
				R ₃								
<u>PERC</u>												
Dry Cleaning	0.36/ 0.59	0.86/ 2.17	6	0.03 (0.22)	-0.10 (-0.64)	-0.11 (-0.97)	-0.18* (-1.85)	-	-	0.11/ 0.39 (0.28/ 1.53)	-0.07/ 0.06 (-0.15/ 0.12)	0.13/ 0.17 (1.19/ 1.53)
<u>FORMALDEHYDE</u>												
UP Foam	0.81/ 0.93	4.39/ 13.14	3	1.07 (1.21)	0.84 (0.71)	-1.26* (-2.49)	-	-	-	-11.36/ -4.25 (-3.61/ -1.89)	7.81/ 15.86 (2.38/ 3.63)	-
Chelating Agents	0.80/ 0.90	12.64/ 26.73	9	0.16* (1.94)	0.20* (3.29)	0.10 (1.19)	-	-	-	-0.96/ -0.88 (-8.59/ -5.22)	0.93/ 1.04 (3.79/ 4.61)	-
<u>ARSENIC</u>												
Herbicide	0.92/ 0.93	20.49/ 25.37	7	0.20 (1.38)	0.18 (0.64)	-0.05 (-0.13)	-0.23 (-0.61)	-0.09 (-0.55)	-	-0.78/ -0.26 (-2.08/ -0.50)	0.98/ 1.30 (1.98/ 6.00)	0.91/ 1.18 (2.14/ 3.92)
CCA	0.94/ 0.97	28.56/ 49.36	7	0.10 (0.39)	0.04 (0.16)	0.37* (2.20)	-	-	-	2.21/ 2.43 (3.58/ 5.91)	-0.21/ -0.17 (-1.12/ -0.73)	-0.79/ -0.46 (-2.69/ -0.93)

Chemical Substance Category	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation			Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂	R ₃			
ACRYLONITRILE													
Fibers	0.65/ 0.76	3.19/ 5.69	7	-0.14 (-1.09)	0.15* (1.98)	0.15* (1.98)	0.04 (0.65)	-0.14 (-1.09)	0.03 (0.50)	0.04 (0.70)	0.23/ 1.05 (0.67/ 1.64)	-0.75/ -0.21 (-1.23/ -0.64)	-0.1/ 0.01 (-1.24/ 0.14)
Resins (Plastics)	0.60/ 0.78	2.22/ 5.21	6	4.77 (0.00)	0.01 (0.06)	0.01 (0.06)	-0.11 (-0.68)	4.77 (0.00)	-0.09 (-0.49)	-0.24* (-2.19)	-0.60/ 0.16 (-0.26/ 0.05)	-0.52/ 0.05 (-0.26/ 0.02)	0.15/ 0.43 (0.16/ 0.51)
Elastomers (Rubber)	0.69/ 0.70	6.02/ 6.08	8	-0.01 (-0.04)	-0.04 (-0.23)	-0.04 (-0.23)	0.04 (0.26)	-0.01 (-0.04)	0.02 (0.12)	0.03 (0.19)	-1.60/ -1.55 (-1.82/ -0.96)	0.83/ 0.95 (0.57/ 1.02)	-
NICKEL													
Alloys	0.68/ 0.80	5.56/ 10.66	8	0.11* (2.23)	-0.01 (-0.10)	0.07 (0.91)	-	0.03 (0.35)	-	-	0.18/ 0.39 (1.31/ 2.66)	-0.13/ -0.005 (-0.56/ -0.02)	-
Compounds	0.23/ 0.56	0.81/ 3.37	8	0.53* (2.50)	0.50* (2.35)	-0.29 (-0.85)	-	0.53/ (1.51)	0.15/ (0.46)	-	-1.42/ 0.08 (-2.39/ 0.09)	1.31/ 2.14 (1.23/ 2.48)	-
Plating	0.11/ 0.57	0.30/ 3.07	7	-0.04 (-0.20)	-0.14 (-0.89)	-0.21 (-1.41)	-0.39* (-2.73)	0.08 (0.34)	-0.19 (-1.00)	-	-0.32/ 0.42 (-0.99/ 1.27)	0.04/ 0.40 (0.06/ 0.58)	-

Chemical Substance Category	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation			Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂	R ₃			
CFCs													
Aerosols	0.77/ 0.92	7.76/ 27.64	7	-0.05 (-0.06)	-0.73 (-0.63)	-	-	-1.99* (-3.71)	-	-	0.86/ 5.09 (0.24/ 0.82)	2.48/ 4.79 (2.00/ 2.58)	-
	Refrigerants	0.62/ 0.85		3.27/ 11.34	0.43* (3.17)	-0.16 (-0.59)	0.34 (1.50)	-	-	-	-4.33/ -0.15 (-1.48/ -0.08)	-0.92/ 1.06 (-0.86/ 0.70)	-

NOTE: t-values in parenthesis.

* Significant at 0.10 level

together with calculated t-ratios, F-ratios, R^2 values, and number of degrees of freedom.² Footnotes to t and F values indicate level of significance. The parameters of the economic variables X_1 , X_2 , X_3 are reported for the range of values that they assume over all PRs and Rs in the separate equations specific to each PR and R (*supra*, p. 3). This Exhibit presents individual coefficients for the PR and R independent variable and gives a range for all X independent variable coefficients. A range is also presented for R^2 and the F-ratio. The coefficients of the PR and R variables, when multiplied by 100, represent the percentage change in the dependent variable associated with a change from 0 to 1 in each of the dummy independent variables. The coefficients of X_1 , X_2 , and X_3 represent a percentage change in the dependent variable resulting from a unit change in the particular independent variable.

The data in Exhibit I present an interesting preliminary picture on a pilot basis of the impact of consumption or production of pre-regulatory (suspect hazard) and regulatory events, as well as the economic variables studied. All else equal, suspect hazard (PR) designation appeared to have some identifiable impact in many cases. In this pilot study, we have singled out such impact as identifiable if it was significant at the 90% confidence level. The usual level for definitive conclusions of significance is a stricter standard of 95% confidence. However, since the study was a pilot effort, the aim was to be over-inclusive in identifying all impacts that were potentially worth follow-up work in a later stage. One or more PR events had a negative impact on uses/operations for cadmium refining and pigment use, benzidine-based dyes, TCE, urea-formaldehyde foam insulation, and nickel (plating only). The categories of chromium (pigments and metal

² The t-ratio for a variable is the ratio between the parameter estimate and its standard error. High t-values indicate high probabilities that the parameter value is indeed significantly different from zero and that the difference did not arise by chance. The F-ratio is used to test the hypothesis that all coefficients are zero except for the intercept. An F-ratio value greater than zero shows this hypothesis to be not true. Values of R^2 represent the percentage of total variation in activity/use explained by all the independent variables taken together.

treatment), and CFCs (aerosols) also represented negative impact of suspect hazard (PR) designation, but below the 90% confidence level.

Some chemical situations analyzed showed an identifiable positive impact of suspect hazard (PR designation). These included: chromium (leather tanning only), formaldehyde (chelating agents only), arsenic (CCA only), acrylonitrile (fiber only), nickel (alloys and compounds), and CFCs (refrigerants only). Two cases showed no discernible negative impact or tendency on consumption or production resulting from suspect hazard designation. These were two of the three categories of acrylonitrile, i.e., elastomers and resins.

Of 75 suspect hazard (PR) events examined, 41 had the expected negative sign (of which 9 were significant at the 90% or higher level), while 34 had a positive sign (of which twelve were significant at the 90% or higher level). It is worth noting that for two chemicals showing significant positive impact of suspect hazard (PR) designation—formaldehyde chelating agents and chromium leather tanning—data were particularly limited in availability and quality, as the reports on these two chemicals make clear.

Actual regulation (R) appeared to have a somewhat mixed, though on balance negative identifiable impact. Of 30 major regulatory (R) events associated with the 25 chemicals studied, half (15) were associated with a positive rather than a negative impact. However, of the 15 with negative impact, five were at or near the 10% level of significance. Of those with positive impact, no cases were significant at the 90% confidence level.

As one would expect, the economic activity, supply, and price variables (X_1 , X_2 , and X_3) had significant impact in a number of cases. For 16 of the 25 chemical cases examined, either economic activity or supply was significant for one or more pairings with a suspect hazard (PR) or regulatory (R) event. Some of this impact was real, and some apparent, as will be discussed below.

In approximately 60% of the cases modeled, the economic activity variable X_1 was characterized by an incorrect (negative) sign, and in all cases where X_1 was significant, this percentage was even higher, i.e. 68%. This result is probably explained by multi-collinearity between the consumption and production adjustment variables U_i and X_1 . U_i is itself an index of economic activity specifically applicable to the uses and operations that we have examined, and its inverse may frequently be correlated with the broader indices of overall chemical activity represented by X_1 . Illustratively, in only eight of 100 cases of pairing with suspect hazard (PR) and regulation (R) variables, is X_1 significant with the correct (positive) sign. Thus, given our use-operations deflator U_i , economic activity (X_1) may simply not possess significant explanatory power for many cases. Resource limitations accounted for by the limited scope of this pilot effort prevented full-scale testing and correction of the models for multi-collinearity.

The supply or feedstock variable X_2 is almost always characterized by a positive sign where it is significant (28 of the 31 cases where it is significant), although it is more frequently characterized by the wrong (negative) sign where it is not significant, i.e., in 65% of the cases. This variable is also much more frequently significant for the 1/3 of cases where suspect hazard (PR) is significant with a positive sign than the 2/3 majority where suspect hazard (PR) has a negative sign (6 of 9 cases). In fact, the majority of cases examined which show significant positive suspect hazard (PR) values also showed significant positive results for the X_2 supply variable as well. This may indicate that resource constraints, production-facilitating technological changes, or other supply factors may be outweighing and indeed dominating the expected negative impact from adverse suspect hazard designation for the substances in question. These substances are formaldehyde chelating agents, nickel alloys and compounds, and chromium leather tanning.

Though it has the predicted (negative) sign in most cases, the relative price variable X_3 does not in general have significant impact. However, there are two exceptions to this statement as well as a third instance worth separate discussion. The first exception is arsenical herbicide, which represents the only instance

where X_3 is significant and has the incorrect (positive) sign. However, this perverse outcome may be explained by the fact that lack of data availability made it necessary to employ a generic price series, consisting of a comparison of arsenical herbicide with all other inorganic herbicides, rather than with the specific inorganic herbicides that competed with arsenic for cotton spraying, which is the main category of arsenical herbicide use. Use of more specific relative price data for competing herbicides could change the parameter estimate of X_3 in this instance.

The second exception is arsenical wood preservatives (CCA). In this case, relative price is significant with the correct (negative) sign. This correct (negative) significant parameter value for X_3 could help explain why the impact of suspect hazard (PR) designation for CCA was reported as significantly positive. Price declines for CCA relative to competing wood reservatives could have outweighed and dominated the expected negative effect over time of suspect hazard (PR) designation, making it spuriously positive.

The third case worth mentioning is acrylonitrile fiber where the t-ratio of -1.24, while not significant, has the correct (negative) sign for the two paired PR cases where impact of suspect hazard designation is (perversely) significantly positive. In this instance, as with CCA above, declining relative price of acrylonitrile fibers may have promoted consumption so as to dominate and overturn the expected negative tendency resulting from suspect hazard (PR) designation, again making PR significantly positive.

In summary, pilot econometric modeling of each of the 25 chemical cases appears to confirm most of the more qualitative and "eyeball" quantitative estimates in the ten reports presented in the previous chapter. Suspect hazard (PR) designation in general appears to have an identifiable dampening impact on use or production whose significance, given the limited number of observations on which the models are based, is somewhat surprising. It should again be emphasized that the results here represent pilot indications on a high-profile chemical sample rather than conclusions for chemicals in-general. Further, the

data show that where PR had a sign contrary to the expected negative one, this perverse result could be explained by the fact that either data were incomplete or sketchy, relative price or supply characteristics overpowered expected negative impact, or both.

By way of specific summary:

- Cadmium refining and pigments show significant negative impact of suspect hazard (PR) designation, while cadmium plating—though not significant—has the correct (negative) sign.
- Benzidine-based dyes and their Direct Brown 95 exemplar show significant negative impact, while the benzidine intermediate and the Direct Black 38 exemplar generally have the correct (negative) sign.
- Chromium pigments and metal treatment show some tendency to negative impact of suspect hazard (PR) designation, though it is not at statistically significant levels. Chromium leather tanning shows incorrect (positive) impact of suspect hazard (PR) designation, but the data series is sketchy.
- TCE shows significant negative impact of suspect hazard (PR) designation.
- PERC shows a negative tendency on production and use from suspect hazard (PR) designation, and one such PR event falls just short of statistical significance.
- Formaldehyde resins used in insulation show significant negative impacts of suspect hazard (PR₃) designation. Chelating agents show incorrect (positive) impact, but this may be explained by the fact that real impact is dwarfed by the high and significant correlation of the chelating agent data series with feedstock supply changes, as well as the lack of availability of a complete chelating agent data series.
- Arsenical herbicide tends to show no significant impact of suspect hazard (PR) designation. However, this result appears to have occurred because: (1) arsenic supply constraints were exerting a powerful counter-influence (X_1 is significant and positive); and (2) the relative price series is mis-specified (X_3 is significant with the wrong, i.e., positive, sign). The wood preservative arsenical (CCA) use shows a mixed impact of suspect hazard (PR) designation. One PR event for CCA is correlated with significant positive impact on its use, but this

may well be explained by the fact that the significant decline in relative price exerted a powerful counter-influence on the expected direction of this PR.

- Acrylonitrile uses in general show no discernible impact, with one notable exception. This exception is the fiber use, for which two suspect hazard (PR) events are correlated with significant positive changes in consumption. Again, in these instances, as with CCA above, relative price is significant, and may be exerting a counter-influence reversing the expected sign.
- Nickel presents a mixed picture. On the one hand, some suspect hazard (PR) events for nickel alloys and compounds are correlated with significant positive impacts on production. In these instances, however, the supply variable X_1 tends to be significantly positive, again indicating the possible counter-vailing impact of this variable. On the other hand, nickel plating consumption has a tendency to be negatively correlated with suspect hazard (PR) events, and in one case, the correlation is significant.
- CFCs also present a mixed picture. In the aerosol use, they show the correct (negative) tendency though it is not significant. On the other hand, CFCs in the refrigeration use show significant positive impact of suspect hazard (PR) activity, because the nonaerosol CFC use category as a whole (including CFC refrigerants) was not specifically affected by designation of CFC as suspect hazard until only recently. Hence, CFC refrigerant consumption increased with general demand growth in the refrigeration and air conditioning industry.

It is interesting to note that some of the results from the econometric analysis shed different or new light on the qualitative analysis performed for each chemical and summarized in the ten reports in the previous chapters. Specifically, the results from the econometric analysis differ from the qualitative results for the following chemicals:

- The sole PR event associated with cadmium pigments showed significant negative impact.
- R_1 for chromium pigments was not significant and was opposite (positive) in expected sign.
- Chromium leather tanning PRs showed significant negative impact.

- The PR events for formaldehyde chelating agents were significant but opposite (positive) in expected sign.
- The pre-regulatory (PR) impact for the arsenic herbicide category was not as significant as expected.
- Two of the three PRs for nickel compounds showed significant positive impact while both Rs showed non-significant positive impact.
- R_1 for CFC aerosols showed significant negative impact while only PR_2 for CFC nonaerosols showed expected negative impact (although not significant in a statistical sense).

B. POOLED CROSS SECTION TIME SERIES MODEL

For the second phase of our econometric analysis, in order to further test the analytic usefulness and explanatory potential of this type of statistical model using public data, an attempt was made to pool all data on a cross section, time series basis, using ordinary least squares (OLS), and analysis of covariance (ANCOVA) and least squares dummy variable (LSDV) analysis. The pooling model used was the same as that previously specified except that data were taken for all 25 chemical uses and operations in the sample. The total number of observations in the pool for each variable except X_3 was given as:

$$N = \sum_{j=1}^{25} t_j$$

where t is total number of years i for the j th chemical. For X_3 , data were available for only seven chemicals rather than the full set of 25, but were available for all years.

Certain standard simplifying assumptions were employed in this pooling test effort. First, as an initial approximation (and subject to potential relaxation and modification in later formal modelling), a linear relationship was assumed to exist between the percentage change in the three exogenous variables (economic activity, supply, and relative price variables) and the percentage change in user or producer behavior and was assumed to be the same for all chemical uses and

EXHIBIT II

ESTIMATE OF PERCENTAGE CHANGES IN ADJUSTED OUTPUT/CONSUMPTION
RESULTING FROM SUSPECT HAZARD DESIGNATION
ON A POOLED CROSS SECTION BASE,
WITH AND WITHOUT PRICE VARIABLE (X_3)

Model Specification	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation			Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂	R ₃			
A. MODELS WITHOUT PRICE VARIABLE													
#1	0.9638	241.33	245	-0.051 (-0.39)	-	-	-	-	-	-	-0.47 (-1.88)**	-0.94 (-4.78)**	-
#2	0.9640	242.75	245	-	-0.16 (-1.24)	-	-	-	-	-	-0.30 (-1.12)	-0.92 (-4.77)**	-
#3	0.9677	271.63	245	-	-	-	-	-0.76 (-5.46)**	-	-	0.13 (0.62)*	-1.03 (-5.61)**	-
#4	0.9637	241.19	245	-	-	-	-	-	-0.021 (-0.13)	-	-0.52 (-2.60)**	-0.92 (-4.62)**	-
#5	0.9640	233.12	244	-0.0048 (-0.036)	-0.16 (-1.18)	-	-	-	-	-	-0.29 (-1.00)	-0.92 (-4.68)**	-
#6	0.9678	261.63	244	-	-	-	-	-0.78 (-5.52)**	-0.13 (-0.83)	-	0.22 (0.92)**	-1.00 (-5.29)**	-
#7	0.9677	261.15	244	0.064 (-0.51)	-	-	-	-0.77 (-5.46)**	-	-	0.057 (0.22)*	-1.02 (-5.45)**	-
#8	0.9681	254.23	243	0.13 (1.00)	-0.22 (-1.71)*	-	-	-0.79 (-5.61)**	-	-	0.32 (1.06)**	-1.00 (-5.36)**	-
#9	0.9681	244.92	242	0.12 (0.93)	-0.20 (-1.56)	-	-	-0.80 (5.61)**	-0.064 (-0.40)	-	0.35 (1.13)**	-0.98 (-5.16)**	-
#10	0.9682	228.38	240	0.11 (0.85)	-0.20 (-1.46)	0.025 (0.17)	-0.15 (-0.83)	-0.80 (-5.50)**	-0.014 (-0.40)	-	0.37 (1.10)**	-1.00 (-5.21)**	-
#11	0.9685	222.87	239	0.13 (0.98)	-0.22 (-1.56)	0.040 (0.27)	-0.26 (-1.34)	-0.79 (-5.47)**	-0.051 (-0.30)	0.51 (1.56)	0.37 (1.10)	-1.05 (-5.40)**	-

EXHIBIT II (continued)

Model Specification	R ²	F Ratio	Degrees of Freedom	Pre-Regulation (Suspect Hazard)				Regulation		Economic Activity X ₁	Supply Feedstock X ₂	Price of Substitutes X ₃
				PR ₁	PR ₂	PR ₃	PR ₄	R ₁	R ₂			
B. MODELS WITH PRICE VARIABLE												
#1	0.9854	464.13	69	-0.14 (-1.00)	-	-	-	-	-	-0.033 (-0.13)	-0.32 (-1.99)**	-0.22 (-1.28)
#2	0.9852	458.60	69	-	-0.056 (-0.42)	-	-	-	-	-0.11 (-0.34)	-0.27 (-1.77)*	-0.17 (-1.01)
#3	0.9875	546.75	69	-	-	-	-	0.55 (-3.64)**	-	0.18 (0.89)	-0.36 (-2.56)**	-0.078 (-0.51)
#4	0.9852	457.99	69	-	-	-	-	-	-0.048 (-0.30)	-0.18 (-0.77)	-0.25 (-1.52)	-0.17 (-1.03)
#5	0.9854	416.31	68	-0.13 (-0.94)	-0.038 (-0.28)	-	-	-	-	0.032 (0.092)	-0.32 (-1.98)*	-0.21 (-1.21)
#6	0.9876	492.03	68	-	-	-	-	-0.56 (-3.67)**	-0.098 (-0.65)	0.27 (1.10)	-0.33 (-2.16)**	-0.06 (-0.41)
#7	0.9876	492.96	68	-0.083 (-0.66)	-	-	-	-0.54 (-3.53)**	-	0.28 (1.10)	-0.40 (-2.63)**	-0.10 (-0.65)
#8	0.9880	461.54	67	-0.045 (-0.35)	-0.20 (-1.56)	-	-	-0.62 (-3.88)**	-	0.68 (1.89)*	-0.41 (-2.73)**	-0.044 (-0.27)
#9	0.9881	421.03	66	-0.062 (-0.47)	-0.19 (-1.38)	-	-	0.62 (-3.84)**	-0.073 (-0.46)	0.73 (1.93)*	-0.39 (-2.46)**	-0.042 (-0.26)
#10	0.9894	398.54	64	-0.13 (-0.97)	-0.16 (-1.11)	0.070 (0.48)	-0.38 (-2.63)**	-0.58 (-3.72)**	0.0086 (0.061)	0.94 (2.51)**	-0.47 (-3.07)**	-0.11 (-0.72)
#11	0.9897	379.20	63	-0.13 (-0.97)	-0.15 (-1.06)	0.089 (0.61)	-0.48 (-2.99)**	-0.55 (-3.54)**	-0.059 (-0.36)	0.95 (2.54)**	-0.51 (-3.29)**	-0.14 (-0.90)

NOTE: t-values in parentheses

* Significant at 0.10 level

** Significant at 0.05 level

operations in the sample. Second, again as a simplifying first approximation for pooling purposes, the relative percentage impact on production/use of the first suspect hazard (PR_1) event was assumed the same for each chemical; and likewise for the second (PR_2), etc.

Two sets of pooled regression analyses were conducted—one for all 25 chemicals for all PR and R variables separately and in combination, paired with economic variables X_1 and X_2 , but not with the relative price variable X_3 for which only limited data were available; and the second only for those seven chemicals for which all data were available including data for relative price variable X_3 . In each set of pooled regressions, 24 intercept dummy variables were also included to allow for the fact that different units were being pooled. The use of log transformation for all continuous variables allowed the comparability needed for pooling purposes.

In order to test the differential impact of the timing and combination of alternative suspect hazard (PR) and regulatory (R) events on use and production, several specifications of the model were included in the analysis based on differing combinations of the PR and R events. Eleven model specifications were tested. These are summarized in Appendix B. The complete results of the pooled analysis for these alternative combinations are presented in Exhibit II.

These pilot results are characterized by high levels of explanatory significance. Perhaps the most significant findings of this pooled analysis are contained in the results of models #8, 9, 10, and 11 without the price variable, and models #10 and 11 with the price variable. They show that, after adjusting for economic factors and the impact of actual regulations (R), the impact of suspect hazard (PR) designation appears to be identifiable, is frequently characterized by the correct (negative) sign, and—based on our preliminary indications—appears to be statistically significant at certain critical stages. For pooled data without the price variable, the suspect hazard (PR) designation is of the correct negative sign for the second and fourth pre-regulatory events. Although only one PR value is statistically significant at the 10% level (PR_2 in model #8), most of the other PR_2

and PR_4 values in these four models are significant at levels close to 10%, i.e., 12% or 14%. For the most limited sample of pooled data with the price variable, suspect hazard designation is significant (at the 5% level) when it is the fourth and last suspect hazard (PR) event in the series.

These preliminary pilot results suggest that additional testing and modelling would be worthwhile. They indicate some interesting preliminary conclusions for further possible testing, as follows:

1. Suspect hazard (PR) designation appears to have a greater dampening impact on use and production when it is second or later in a series of pre-regulatory events rather than earlier. (According to these preliminary results, no impact at all is associated with the first pre-regulatory event PR_1 .) At least two interpretations on this finding are possible, and both may be correct to a greater or lesser degree. First, it may be that the greater impact of a later suspect hazard (PR_2 or PR_4) event represents a lagged effect from the first event. Second, the greater impact of the second event may be the result of the growing involvement of federal regulatory agencies in suspect hazard designation activity for the chemical in question. As the report makes clear for the limited sample of ten chemicals studied, first events in our sample tended to be industry-sponsored, academic, or research agency studies rather than pre-regulatory efforts involving the relevant federal agency with actual regulatory authority. In general, it was only with the second or later event that federal regulatory agencies began to become involved. These results possibly could be interpreted to mean that chemical producers may only tend to take the first signs of suspect hazard designation seriously when they see federal agency involvement beginning to occur.

2. While suspect hazard designation following the first instance has significant negative impact on use/production, this impact appears to be substantially less than that of the first actual regulation (R_1). Coefficient estimates for R_1 are approximately three of four times as high as for PR_2 . However, there is reason to believe that the differential impact may be narrower

than indicated by this pooled analysis. This may be because data limitations associated with two important members of our sample—formaldehyde chelating agents and chromium leather tanning—may have contributed spurious positive impacts associated with suspect hazard (PR) designation. Also, in some cases studied, R_1 was actually the first regulatory event to occur before any suspect hazard PR event occurred. As such, it can dwarf the impact of PR_1 and subsequent PRs.

3. Regulatory events after the first (R_1) were associated with substantially diminished and statistically insignificant impact on production and use, as illustrated by almost all the models. For a multi-regulated chemical product or use, the first regulation appeared to be by far the most important one.

The tentative findings of this pooled analysis based on public data for a limited sample of high-profile chemicals and activities, suggested that it would be useful to develop the pilot model further to the extent possible by including additional observations. Public data on three additional prominent chemicals were available to provide some additional data observations, and it was felt that the inclusion of such additional observations on the pooled model would provide a somewhat richer data base to illuminate not only the three embryonic conclusions suggested above, but also some additional relevant issues such as:

- Whether the consumption/production behavioral impact of suspect hazard designation and regulation occurred with any kind of time lag;
- The extent to which the impact of suspect hazard designation was affected by widespread media publicity accompanying the suspect hazard and regulatory designation event(s);
- Whether the impact of suspect hazard and regulatory designation was related to the way in which the dependent variable was defined, i.e., whether it was defined in terms of production/operations (e.g., refining), or in terms of type of usage or consumption pattern;
- Whether the impact of suspect hazard designation was different if a regulatory agency had been involved in the designation than if no such agency involvement had occurred (e.g., an academic study); and

- Whether differential impact occurs that is related to the identity of the federal agency involved (i.e., EPA, FDA, OSHA, etc.).

To this end, the data set for the model was extended to include three additional chemicals and eight additional uses. The results are presented in the next section.

C. RESULTS OF THE POOLED CROSS SECTION TIME SERIES MODEL WITH EIGHT ADDITIONAL CHEMICAL USES INCLUDED

The three additional chemicals representing eight uses that were added to the data base for purposes of further development of the pooled cross-section model were selected by the same process described earlier in the report. These chemicals and their uses were:

- PBB's (flame retardants)
- PCB's (electrical)
- Asbestos (three uses)
 - A. Construction
 - B. Paper
 - C. Fibers
- Lead (three uses)
 - A. All chemical uses in aggregate
 - B. Pigments
 - C. Batteries

Inclusion of these new data expanded the number of observations for testing applicable models by approximately 40 percent.

The pooled cross-section models described above were tested again by adding the values from publically available data on relevant economic and regulatory variables for eight additional chemical uses to the original public data base of 25 chemical uses/operations. Sources of values for relevant variables for these eight new uses are summarized in Appendix C.

Pilot findings for each of these six analysis issues shall be discussed in order. Findings with the data added for eight new uses are presented using full-scale (multiple PRs and Rs) models 10 and 11 from Exhibit II, and are summarized in Exhibits III (model 10) and IV (model 11) below. Findings are also available for the other, simpler model specifications (1 through 9), previously presented in Exhibit II, but are not presented in this report. They will be separately forwarded to interested readers. In general, results formed by adding the eight new chemical uses to the data base for these other simpler model specifications 1 through 9 of Exhibit II are similar to the new results for models 10 and 11.

It should be noted that the issue of the extent to which the impact of suspect hazard designation depended on whether or not a federal regulatory agency was involved, and if so whether impact differed by agency could only be tested with the eight new chemical uses at a level of simple model specification—using models 2 and 3 of Exhibit II rather than models 10 and 11 of that Exhibit. Results for this issue are separately summarized below without reference to Exhibits III and IV.

1. Findings

Findings on five major issues are presented: (1) whether the initial directions and findings described in the previous section continued to be valid (on the same preliminary pilot basis) with the addition of three new chemicals and eight new uses; (2) whether the consumption/production behavioral impact of suspect hazard designation and formal regulation occurred with any kind of time lag; (3) the extent to which the impact of suspect hazard designation was affected by widespread media publicity accompanying the suspect hazard and formal regulatory designation event(s); (4) whether the impact of suspect hazard and formal regulatory designation was related to the way in which the dependent variable was defined, i.e., whether it was defined in terms of production/operations (e.g., refining), or in terms of type of usage or consumption pattern; (5) whether the impact of suspect hazard designation was different if a regulatory

EXHIBIT III

SUMMARY OF COEFFICIENTS AND SIGNIFICANCE LEVEL FOR POOLED TIME SERIES, CROSS SECTION ANALYSIS WITH EIGHT NEW CHEMICAL USES BASED ON MODEL 10 OF EXHIBIT II

	Values for 25 Chem. Uses w/o Price Variable (Model 10, Exhibit II)	New Data for 33 Chem. Uses w/o Price Variable	Data for 33 Chem. Uses Lagged 1-Yr. for PR and R Var. w/o Price Var.	Data for 33 Chem. Uses With a Consumer Var. Added w/o Price Var.	Data for 18 Chem. Uses w/o Price Variable Use Dep. Var.	Data for 15 Chem. Uses w/o Price Variable Prod. Dep. Var.	Data for 7 Chem. Uses With Price Var. (Model 10, Exhibit II)	Data for 7 Chem. Uses With PR & R Var. Lagged 1-Yr. With Price Var.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PR ₁	0.11 (0.85)	0.23 (1.89)*	0.00 (0.01)	0.31 (2.53)**	0.31 (1.86)*	-0.09 (-0.58)	-0.13 (-0.97)	-0.057 (-0.40)
PR ₂	-0.20 (-1.46)	-0.22 (-1.74)*	-0.20 (-1.59)	-0.18 (-1.39)	-0.40 (-2.37)**	-0.03 (-0.16)	-0.16 (-1.11)	-0.32 (-2.19)**
PR ₃	0.025 (0.17)	-0.04 (-0.28)	-0.17 (-1.24)	-0.06 (-0.49)	0.18 (1.09)	-0.06 (-0.31)	0.070 (0.48)	0.067 (0.39)
PR ₄	-0.15 (-0.83)	-0.34 (-2.05)**	0.00 (0.01)	-0.38 (-2.35)**	-0.38 (-2.03)**	-0.17 (-0.61)	-0.38 (-2.63)**	-0.29 (-1.72)*
R ₁	-0.80 (-5.50)**	-0.50 (-3.82)**	-0.58 (-4.58)**	-0.47 (-3.60)**	-0.40 (-2.17)**	-0.40 (-2.35)**	-0.58 (-3.72)**	-0.50 (-3.49)**
R ₂	-0.014 (-0.085)	-0.07 (-0.52)	-0.02 (-0.15)	-0.03 (-0.24)	-0.09 (-0.46)	-0.14 (-0.76)	0.0096 (0.061)	0.12 (0.73)
R ₃	--	--	-0.46 (-2.11)**	--	--	--	--	--
X ₁ (Economic Activity)	0.37 (1.10)	-0.05 (-0.21)	0.36 (1.49)	-0.03 (-0.12)	-0.32 (-1.04)	0.25 (0.69)	0.94 (2.51)**	0.97 (2.62)**
X ₂ (Supply Feedstock)	-1.00 (-5.21)**	-0.19 (-1.83)*	-0.19 (-1.92)*	-0.15 (-1.53)	0.12 (1.16)	-1.87 (-7.92)**	-0.47 (-3.07)**	-0.37 (-2.36)**
X ₃ (Price)	--	--	--	--	--	--	-0.11 (-0.72)	-0.15 (-0.94)
CA (Consumer Awareness)	--	--	--	-0.42 (-2.88)**	--	--	--	--
R ²	0.9682	0.9501	0.9515	0.9513	0.8622	0.9792	0.9894	0.9890
F ratio	228.38	166.14	166.62	165.68	48.56	314.53	398.54	385.16
DF (Degrees of Freedom)	240	349	348	348	194	147	64	64

* Significant at 0.10 level

** Significant at 0.05 level

EXHIBIT IV

SUMMARY OF COEFFICIENTS AND SIGNIFICANCE LEVEL FOR POOLED TIME SERIES, CROSS SECTION ANALYSES WITH EIGHT NEW CHEMICAL USES BASED ON MODEL 11 OF EXHIBIT II

	Values for 25 Chem. Uses w/o Price Variable (Model 11, Exhibit II)	Data for 33 Chem. Uses w/o Price Variable	Data for 33 Chem. Uses Lagged 1-Yr. for PR and R Vars. w/o Price Var.	Data for 33 Chem. Uses With a Consumer Awareness Var. Added w/o Price Var.	Data for 18 Chem. Uses w/o Price Variable, Use-Adjusted	Data for 15 Chem. Uses w/o Price Variable Prod. Adjusted	Data for 7 Chem. Uses With Price Var. (Model 11, Exhibit II)	Data for 7 Chem. Uses With PR & R Vars. Lagged 1-Yr. With Price Var.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PR ₁	0.11 (0.85)	0.23 (1.86)*	0.00 (0.01)	0.31 (2.51)**	0.31 (1.86)*	-0.09 (-0.57)	-0.13 (-0.97)	-0.057 (-0.40)
PR ₂	-0.20 (-1.46)	-0.22 (-1.72)*	-0.20 (-1.59)	-0.18 (-1.39)	-0.41 (-2.42)**	-0.01 (-0.07)	-0.16 (-1.08)	-0.32 (-2.17)**
PR ₃	0.025 (0.17)	-0.04 (-0.29)	-0.17 (-1.24)	-0.06 (-0.49)	0.19 (1.15)	-0.04 (-0.19)	0.089 (0.61)	-0.068 (0.40)
PR ₄	-0.15 (-0.83)	-0.32 (-1.92)*	0.00 (0.01)	-0.38 (-2.30)**	-0.32 (-1.64)	-0.15 (-0.56)	-0.48 (-2.98)**	-0.29 (-1.69)*
R ₁	-0.80 (-5.50)**	-0.50 (-3.82)**	-0.58 (-4.58)**	-0.47 (-3.59)**	-0.40 (-2.19)**	-0.40 (-2.34)**	-0.55 (-3.54)**	-0.50 (-3.43)**
R ₂	-0.014 (-0.085)	-0.05 (-0.36)	-0.02 (-0.15)	-0.03 (-0.23)	-0.00 (-0.02)	-0.17 (-0.88)	-0.059 (-0.36)	0.12 (0.68)
R ₃	--	-0.10 (-0.50)	-0.46 (-2.11)**	-0.00 (-0.000)	-0.26 (-1.12)	0.23 (0.59)	0.30 (1.39)	0.030 (0.11)
X ₁ (Economic Activity)	0.37 (1.10)	-0.05 (-0.18)	0.36 (1.49)	-0.03 (-0.12)	-0.31 (-0.99)	0.24 (0.66)	0.95 (2.54)**	0.97 (2.60)**
X ₂ (Supply Feedstock)	-1.00 (-6.21)**	-0.19 (-1.85)*	-0.19 (-1.92)*	-0.15 (-1.53)	0.12 (1.13)	-1.86 (-7.86)**	-0.51 (-3.29)**	-0.38 (-2.33)**
X ₃ (Price)	--	--	--	--	--	--	-0.14 (-0.90)	-0.15 (-0.94)
CA (Consumer Awareness)	--	--	--	-0.42 (-2.83)**	--	--	--	--
R ²	0.9682	0.9501	0.9515	0.9513	0.8631	0.9792	0.9897	0.9890
F ratio	228.38	161.75	166.62	161.27	46.80	299.55	379.20	355.52
DF (Degrees of Freedom)	240	348	348	347	193	146	63	63

* Significant at 1.10 level

** Significant at 0.05 level

agency had been involved in the designation than if no such agency involvement had occurred (e.g., an academic study); and (6) whether differential impact occurs that is related to the identity of the federal agency involved (i.e., EPA, FDA, OSHA, etc.).

a. Comparison of Results Using New (Exhibits III and IV) Versus Old (Exhibit I) Data

In this section, we compared the results of using the old sample of 25 uses/activities and the new models containing eight additional uses. In general, the direction of pilot findings suggested by 25 chemical activities/uses was reinforced by the inclusion of public data on eight additional uses. Columns 1 and 2 of Exhibits III and IV show the comparison. The PR2 variable, negative and close to our baseline (90%) criterion of significance from the previous model, became significant at the 10% level, and the size of the negative impact coefficient increased slightly, i.e. from .20 to .22. R1 remained very significant (at the 1% level), but the size of the coefficient decreased somewhat (i.e., from -.80 to -.50). For PR4, the coefficient doubled in size and became significant, while maintaining its (correct) negative sign. The economic activity variable X_1 remained insignificant with the new data, and the supply feedstock variable X_2 remained negative and significant, though at a lower (10%) level.

Perhaps the most interesting finding for our sample of high-profile chemicals was that in both models 10 (Exhibit III) and 11 (Exhibit IV), PR_1 increased (from .11 to .23) and became significant at the 10% level. This surprising result, in conjunction with the significant negative value for PR_2 , suggests that firms may temporarily increase their consumption/use behavior after the first suspect hazard designation event, before reducing it considerably after the second. One possible explanation of this temporary increase as far as consumption is concerned is that firms first react to the initial suspect hazard event by drawing down their levels of inventory to such an extent that net consumption is increased for the year, even though production might fall. Analysis of other issues to be presented below reinforces the validity of this

explanation. Still another interesting, though less important finding was that with the new data, PR_4 in models 10 and 11 became more strongly negative and significant, whereas it was not significant in models using the old data.

b. Effect of Time Lags on Relationship Between Suspect Hazard Designation, Regulation, and Chemical Use/Activity

In this section, we examined the timing of the impact of suspect hazard designation, i.e., whether suspect hazard designation and regulation affect firm behavior only after they have been in place for a certain period of time. To test this hypothesis, the PR and R variables were lagged one year, and these lagged variables were then used to replace unlagged PR and R values in models 10 and 11. Models were estimated both with and without the price-of-substitutes variable X_3 . Results for models 10 and 11 without the X_3 variable are reported in Column 3 of Exhibits III and IV, respectively, and can be compared with the values without lags in Column 2. Results for models 10 and 11 with the X_3 price-of-substitutes variable are reported in Column 8 of Exhibits III and IV, and can be compared with unlagged values in Column 7 of those same Exhibits. These lagged-unlagged results show interesting contrasts and findings, as follows:

(i) Time Lag Findings for Models without Price-of-Substitutes Variable X_3

Perhaps the most interesting finding here concerns PR_1 . When PR_1 was lagged a year, it lost its significant positive value, and in some models (not presented) even became negative (though not at a significant level). This disappearance of positive impact of the first suspect hazard designation after a year is consistent with the hypothesis suggested above that the initial reaction to a suspect hazard designation by firms in our high-profile sample may be to draw down inventory and to temporarily increase consumption, even though production may itself be declining as a result of the suspect hazard designation. After a year, this inventory-induced positive net value of the impact coefficient would be expected to disappear.

Other PR events after the first PR_1 also showed some interesting changes when they were lagged a year, as shown by comparison of columns 2 and 3. PR_2 remained negative, while the negative effect of PR_3 became stronger (from -.04 to -.17) when lagged, although not significant at the .10 level. PR_4 completely lost its impact.

The negative effect of R_1 on use/activity under a one-year lag specification in this pilot test continued to be substantial and very significant, more so in certain dimensions than it was under the no-lag assumption. As measured by coefficient size, the impact of R_1 was substantially larger than the impact of PR_2 . As shown by comparison of columns 2 and 3, R_1 became larger and more significant when it was lagged a year than when it was not, and was more significant than R_2 by about the same proportion whether it was lagged or not. Also interesting is that under the one-year lag regime, the negative value of R_3 became significant (Exhibit IV), whereas it was not significant when it was unlagged.

It is also worth noting that almost all the PR and R values when lagged had the predicted negative sign, just as they did in the unlagged models.

Values for the economic activity and supply feedstock variables X_1 and X_2 did not appear to change dramatically when PR and R events were lagged, as opposed to when they were unlagged.

(ii) Time Lag Findings for Models with Price-of-Substitutes Variable X_3

When PR and other independent variables were lagged in models 10 and 11 containing a price of substitutes variable, X_3 (column 8), only one major change occurred from models (column 7) where values were unlagged: the coefficient of PR_2 went from non-significance to a high level of significance (column 8). Moreover, both the size and level of significance of its coefficient value in the lagged models with the price-of-substitutes variable X_3 were higher than in the unlagged models without X_3 (column 2). Other PR and R values did not change significantly under an X_3 /time lag modeling scenario. PR_1 did not

change substantially from its non-lagged/ X_3 value. It kept the (correct) negative sign, though at a reduced coefficient level, and was not significant. PR_4 stayed negative and significant, though at a reduced level and rate. The values for the R_1 and R_2 and X_1 , X_2 , and X_3 variables did not change appreciably when the PR and R variables were lagged.

c. Impact of Increased Consumer Awareness through Media Publicity on Level of Chemical Use and Activity

In this section, we examined whether or not suspect hazard designation or formal regulation would have a greater impact on chemical consumption and use if they were accompanied by extensive media publicity. The question to be examined was whether such adverse publicity might act as an additional factor contributing to reduced consumer demand for the chemical or products containing it, or to a greater industry-wide awareness of a hazard, resulting in faster production curtailment responses. To test this hypothesis, the models were run with the addition of a new dummy variable specification, called a consumer awareness variable, that reflected whether or not a chemical was characterized by extensive media publicity. Chemicals were assigned a value of 1 for all observations after the initial year of suspect hazard designation if such designation had been accompanied by high levels of media publicity, and 0 if they were not. The criterion for assignment consisted of publication of the suspect hazard status of the chemical in at least three news articles in major national publications in the years in which suspect hazard events were recorded. It should be noted that a large enough number of observations was available only to test the models which did not include the price-of-substitutes variable X_3 . These models were tested only without time lags.

The results of the analysis are summarized in Column 4 of Exhibits III and IV. They indicate, interestingly, that the consumer-awareness-through-media-publicity variable, designated CA, was strongly negative and significant at the 1% confidence level. Even with the inclusion of this separate CA variable, however, PR_1 and PR_2 continued to show a strong and significant impact. PR_1 continued to have its positive impact, the size of which increased with the addition of the

independent CA variable. PR_2 stayed negative and close to significant, though—as comparison with Columns 2 and 3 shows—slightly less so than if CA had not been included. The impact of R_1 and R_2 was reduced about 5-10% by the inclusion of the CA variable, though the general significance patterns stayed the same. The economic variables X_1 and X_2 were not affected to any great extent by the inclusion of the CA variable.

d. Impact of Alternative Specifications of Chemical Activity in Estimating the Effect of Suspect Hazard and Regulatory Designation

In this section, we examined whether the manner in which chemical activity as a dependent variable was specified affected the amount of impact which suspect hazard designation or formal regulation would have on it. In our study, chemical activity was defined in two ways: for 18 of 33 cases, it was defined in terms of use-adjusted consumption; for the remaining 15 chemicals, it was defined in terms of production or industrial operations (i.e., refining). The models were estimated separately for all pooled data in each of the two sets of cases. The two sets of results are provided in columns 5 and 6, and show interesting and substantial contrasts in several dimensions.

The pooled data for producer operations (column 6) showed no significant impacts associated with any of the PR suspect hazard designation variables, or the R_2 and R_3 variables. However, for the most part these variables had the predicted negative sign. The R_1 variable was negative and significant in all models. The impact of the supply or feedstock variable X_2 was negative and significant at the 1% level the model, while the economic activity variable X_1 was insignificant.

On the other hand, the pooled set of data where the dependent variable was defined in terms of consumption/use (column 5) showed that suspect hazard and regulatory designation had a substantial impact. PR_1 was significant, though again with positive sign, while PR_2 and PR_4 were strongly negative and for the most part significant at the 1% confidence level. R_1 was likewise strongly

negative and significant in almost all models. Interestingly, for this set of pooled data limited to consumption and use rather than operations, the impact of the second suspect hazard designation (PR_2) turned out to be of the same order of magnitude as that of regulation.

As indicated above, one possible interpretation of the positive PR sign for the pooled consumption series is that firms, in response to the first suspect hazard designation event, temporarily increased consumption through a drawing down of inventory before reducing it in response to the second such event. This interpretation was reinforced by the findings above with respect to time lags. It was also somewhat reinforced by the fact that this positive PR impact was not observed when the PR_1 variable was defined in terms of production operations, data for which are not inventory-sensitive.

e. Impact of Agency Involvement on Suspect Hazard and Regulatory Designation

In this section, we examined whether federal agency regulatory involvement in suspect hazard designation had a different impact on consumption/production behavior than designation which involved some institution other than a federal agency (e.g., an academic research study). The hypothesis examined was that agency involvement in suspect hazard designation would lead to a stronger negative impact on consumption/production than if no regulatory agency was involved, because of the presumably greater credibility of such an agency and its threat of future regulation.

The focus in this initial examination was to distinguish between agency and non-agency involvement for PR_1 and PR_2 in models 1 and 2 only without the price variable X_3 , respectively. The suspect hazard events used to make the distinction are described in Appendix C. Resource constraints prevented us from testing other models, particularly the full-scale models 10 and 11. In addition, the small number of observations prevented us from testing any models that included the price-of-substitutes variable X_3 .

Results showed that on this limited-test pilot basis, agency involvement in suspect hazard designation did appear to make some difference. The coefficient for PR_1 in model 1 without distinguishing between agency and non-agency involvement was positive (.093), but not significant ($t=0.83$). Once agency and non-agency involvement were distinguished, however, the picture changed. For PR_1 , the coefficient for suspect hazard designation events which did not involve a federal agency showed up strongly positive (+0.25) and significant at the 10% confidence level ($t=1.71$); while the coefficient for events involving a federal agency showed up with the predicted (though slight) negative sign (-0.02), though it was not significant ($t=-.18$). Thus, based on these very limited data and tests, it appeared that the first suspect hazard designation event PR_1 was associated with increased (rather than decreased) consumption or production when it did not involve a federal agency, but that federal agency involvement turned this impact slightly (though not significantly) negative. It is important to note that this finding is not inconsistent with the inventory-drawdown hypothesis presented above as an explanation for the positive sign of PR_1 . Rather, it could indicate that such inventory drawdown behavior may simply be less likely to play a significant role when suspect hazard designation involves a federal regulatory agency than when it does not.

The coefficient for PR_2 in model 2 without distinguishing between agency and non-agency involvement was negative and significant at the 10% confidence level (-0.18, $t=-1.68$). Once agency involvement was distinguished, this negative impact increased (to -0.35) and became even more significant (to $t=-2.74$, 1% confidence level); while the coefficient for suspect hazard designation characterized by non-federal-agency involvement was slightly positive (+0.036), though not significant ($t=.26$).

Although preliminary tests in two limited models with partial data showed that agency involvement may be a significant factor explaining the strength and direction of the impact of suspect hazard events, additional testing with fuller-scale models and richer data base are needed to indicate whether these impacts are real.

f. Role of Agency Identity Associated with Impact of Regulation

We also conducted an initial preliminary examination to address whether there were any differences in the impact of regulation among the various agencies examined. We tested model 3 (whose independent variables were R_1 , X_1 , and X_2) by creating dummy variables to differentiate R_1 events in terms of whether they originated with OSHA, EPA, or FDA. The analysis based on this limited initial test showed that each of these variables had the expected negative sign, and was significant at the 10% confidence level or higher. EPA regulations had the largest and most significant (1% level) impact on use/operations. Coefficients and their t-values were: for OSHA, -.24 and $t=-1.82$; for EPA, -1.38 and $t=-3.90$; and for FDA, -.77 and $t=-2.78$. Again, expanded testing with a larger data base and full-scale modelling are needed to determine the real existence and significance of these impacts.

D. SUMMARY AND CONCLUSIONS

Exhibits V and VI present a summary of major findings from the pooled statistical regression analysis based on public data for our high-profile chemical sample as to the impact of various aspects of suspect hazard and regulatory designation on chemical consumption and activity. Exhibit V summarizes the average percentage change in activity as a result of suspect hazard designation, media publicity associated with such designation, and actual regulation for the subset of 18 sampled chemical activities where the dependent variable was defined in terms of consumption and for the full set of 33 chemicals when the dependent variable was defined in terms of either consumption or production.

Exhibit VI compares changes in activity (consumption or production) on the full pooled set of 33 chemical uses as a result of suspect hazard and regulatory events: (1) where the event was and was not characterized by extensive media publicity; and (2) where the event was and was not characterized by a time lag. In addition, impacts are compared for suspect hazard events sponsored by federal regulatory agencies versus those sponsored by others.

EXHIBIT V
SUMMARY OF FINDINGS

<u>Average Percentage Change After:</u>	<u>Average % Change in Consumption (18 Chemicals)</u>	<u>Average % Change in Consumption/ Production (33 Chemicals)</u>
1st Suspect Hazard Event	+31% *	+23% *
2nd Suspect Hazard Event	-41% **	-22% *
3rd Suspect Hazard Event	+19%	-4%
4th Suspect Hazard Event	-32%	-32% *
Media Publicity for Suspect Hazard Events versus No Media Publicity	Not Tested	-42% **
1st Regulatory Event	-40% **	-50% **
2nd Regulatory Event	0%	-5%
3rd Regulatory Event	-26%	-10%

- * Significant at 10% level of statistical significance.
 ** Significant at 5% level of statistical significance.

EXHIBIT VI

COMPARISON OF IMPACT OF SUSPECT HAZARD (SH) AND REGULATION (R) EVENTS ON CONSUMPTION/PRODUCTION (C/P) RESULTING FROM:

A. <u>Media Publicity</u>	% Change in C/P for Events Without Media Publicity	% Change in C/P for Events With Media Publicity
SH Event #1	-23% *	+31% **
SH Event #2	-22% *	-18%
SH Event #3	-4%	-6%
SH Event #4	-32% *	-38% **
R Event #1	-50% **	-47% **
R Event #2	-5%	-3%
R Event #3	-10%	0%
B. <u>Federal Regulatory Agency Status versus Non-Agency Status for Suspect Hazard Events</u>	% Change in C/P for Non-Federal SH Events	% Change in C/P for Federal SH Events
SH Event #1	+25% *	-2%
SH Event #2	+3.6%	-35% **
C. <u>Lag of One Year in Impact</u>	% Change in C/P No Time Lag	% Change in C/P One-Year Time Lag
SH Event #1	+23% *	0%
SH Event #2	-22% **	-20%
SH Event #3	-4%	-17%
SH Event #4	-32% *	-38% **
R Event #1	-50% **	-58% **
R Event #2	-5%	-2%
R Event #3	-10%	-46% **

* Significant at 10% level

** Significant at 5% level

*** NOTE: This federal/non-federal test was run on a simplified model rather than the full model because insufficient data were available to run the full model

Major conclusions can be summarized as follows:

- Taking all factors into account, suspect hazard events had a very important impact on consumption, one that was sometimes statistically significant. This impact depended on where these events were in the total sequence of suspect hazard events for a given chemical. Firms decreased production/consumption significantly in response to suspect hazard designation, but only after the second suspect hazard event rather than immediately (See Exhibit V).
- After the first suspect hazard event, firms increased consumption temporarily, before going into a reduction mode by the time of the second suspect hazard event. Economically, this meant that firms drew down their levels of inventory in response to the first suspect hazard designation of a chemical, leading to temporary increase in consumption. Evidence for this was that:
 - This effect disappeared when it was lagged a year (See Exhibit VI).
 - The effect did not exist where only impact on production was examined, rather than impact on consumption, and it was intensified when consumption only was examined.
- When significant impacts of suspect hazard designation on consumption only (18 chemicals) were compared with their counterpart significant impacts on both production and consumption (by taking 15 chemicals out of the 33-chemical data pool where the dependent variable was defined in terms of production only), these impacts were substantially higher in the consumption-only dependent variable case. This provides some initial indication that the impact of suspect hazard designation events on consumption in specific chemical uses may be larger than the impact on general production (See Exhibit V).
- Regulation itself had a significant dampening impact on chemical consumption/activity. Impact for regulation was greater than for suspect hazard designation when all 33 chemical activities were examined. If only consumption activities were examined, the impact of suspect hazard designation was almost as great as that of regulation (See Exhibit V). Media publicity attached to a suspect hazard designation made the impact of suspect hazard designation even greater.

- Media publicity reduced consumption directly over and above the reduction associated with the suspect hazard event itself (See Exhibit V).
- Media publicity tended to intensify the impact of actual suspect hazard designation, accelerating initial inventory draw-down (See Exhibit VI).
- The impact of suspect hazard designation on consumption was not significantly different if it was lagged a year rather than tested as a simultaneous event. Impact of regulation appeared to be slightly intensified when it was lagged. Lagging however, did neutralize the positive impact of the first suspect hazard designation (See Exhibit VI).
- Limited testing showed that the dampening impact on consumption/production of suspect hazard designation was greater when the suspect hazard events are federal as opposed to non-federal events (See Exhibit VI).
- Economic variables—feedstock supply, general level of activity, price of substitutes—did not play as significant a role in explaining changes in consumption as did suspect hazard and regulatory events. This may be because consumption of chemicals was already adjusted as a part of our original specification of the model for changes in general economic activity levels with respect to the output products in which they were used. Thus, addition of other economic variables did not appear to make much of a difference.

Again, it must be noted that these conclusions have highly limited significance, i.e., they apply only to a data base of 33 high-profile chemicals, and only on the basis of very simple econometric modelling specifications using publically available data exclusively. Even on this basis however, the story they tell appears to be consistent, interesting, and worth pursuing further.

APPENDIX A
DATA USED IN ECONOMETRIC ANALYSIS

ACRYLONITRILE (AN)

	<u>Fibers</u>	<u>Resins (Plastics)</u>		<u>Elastomers</u>
		AN Fiber production	Production of AN Resins (ABS/SAN)	
Y _i				Nitrile Rubber production
U _i		Textile mill products production index	Plastic materials production index	Total rubber gaskets, hose, and belting production
PR ₁		1971 ACGIH recommendation	1971 ACGIH recommendation	1971 ACGIH recommendation
PR ₂		1977 Dow & DuPont cancer reports	1977 Dow & DuPont cancer reports	1977 Dow & DuPont cancer reports
PR ₃		1977 NIOSH recommendation	1977 NIOSH recommendation	1977 NIOSH recommendation
PR ₄		1979 EPA actions (2)	1979 EPA actions (2)	1979 EPA actions (2)
R ₁		1971 OSHA standard (20ppm)	1971 OSHA standard (20ppm)	1971 OSHA standard (20ppm)
R ₂		1978 OSHA standard (2ppm)	1978 OSHA standard (2ppm)	1978 OSHA standard (2ppm)
R ₃		1980 EPA Final Water Rule	1980 EPA Final Water Rule	1980 EPA Final Water Rule
X _{1i}		CSM ¹	CSM	CSM
X _{2i}		AN Production	AN Production	AN Production
X _{3i}		Relative price of AN fibers to wool	Relative price of ABS/SAN resins to styrene resins	Not available

¹Federal Reserve Board's Chemical and Synthetic Materials Index

ARSENIC

Herbicide As_2O_3

Y_i	Total Ag demand for arsenic
U_i	Total cotton production
PR_1	1973 NIOSH study
PR_2	1974 OSHA meeting
PR_3	1975 OSHA proposal
PR_4	1976 EPA proposed interim drinking water limit
R_1	1978 OSHA standard
R_2	—
R_3	—
X_{1i}	CAP ¹
X_{2i}	Total U.S. arsenic supply
X_{3i}	Relative price of As_2O_3 to all other organic herbicides

¹ Federal Reserve Board's Chemical and Allied Products Index

TCE

Metal Degreasing

	CCA	
	CCA production	TCE consumption for metal degreasing
	Total hours worked in wood preserving industry	Total PCE 1,1,1 TCE used in metal degreasing
	1973 NIOSH study	1974 NIOSH study
	1978 EPA information request	1975 OSHA proposal, carcinogenicity findings and EPA interim regulations
	1981 EPA proposed regulatory options	1980 EPA proposed standard
	—	—
	—	—
	—	—
	—	—
	CAP	CAP
	Total U.S. arsenic supply	Ethylene and ethylene-dichloride production
	Relative price of CCA to PCP	Relative price of TCE to 1,1,1-TCE

BENZIDINE-BASED DYES

	<u>Benzidine</u>	<u>Benzidine-based Dyes</u>	<u>Direct Black 38</u>
Y _i	Benzidine production	Benzidine production	Production land imports of D. Blk. 38
U _i	Production of dye cyclic intermediates and benzenoid chemical imports	Production and imports of total Direct Dyes	Production and imports of total Direct Dyes
PR ₁	1973 NIOSH study	1973 NIOSH study	1973 NIOSH study
PR ₂	—	1975 NIOSH alert and Japanese study	1975 rat study
PR ₃	—	1977 NIOSH study	1978 NIOSH recommend.
PR ₄	—	1979 EPA TSCA rule	—
R ₁	1974 OSHA benzidine standard	1974 OSHA benzidine standard	1974 OSHA benzidine standard
R ₂	—	—	1980 OSHA guidelines
R ₃	—	—	—
X _{1i}	CAP	CAP	CAP
X _{2i}	Nitrobenzene production	Nitrobenzene production	Nitrobenzene production
X _{3i}	Not Relevant	Not Relevant	Not Relevant

DYES (continued)

	<u>Direct Brown 95</u>	<u>Home (Consumer) Dyes</u>
Y _i	Production and imports of D. Bwn. 95	Production of consumer Benzidine-based Dyes
U _i	Production and imports of total Direct Dyes	No use-adjustment used
PR ₁	1975 rat study	1980 OSHA alert and CPSC proposal
PR ₂	1978 NIOSH study specific to Direct Brown	—
PR ₃	—	—
PR ₄	—	—
R ₁	1974 OHSB benzidine standard	—
R ₂	1980 OSHA guidelines	—
R ₃	—	—
X _{1i}	CAP	CAP
X _{2i}	Nitrobenzene production and imports	Nitrobenzene production and imports
X _{3i}	Not relevant	Not relevant

CADMIUM

	<u>Refining</u>	<u>Pigments</u>	<u>Plating</u>
Y _i	Domestic Cd production	Cd pigment production	Consumption Cd in Plating
U _i	Domestic Cd production and imports	Total synthetic inorganic pigment production	Total hours worked in metal treating industry
PR ₁	1976 NIOSH study	1976 NIOSH study	1976 NIOSH study and government study
PR ₂	1978 EPA proposed waste water effluent guidelines	1980 IRLG evaluates ban	1977 Final workshop.
PR ₃	—	—	1978 EPA proposed waste water effluent guidelines
PR ₄	—	—	—
R ₁	1974 OSHA standard	—	1979 EPA finalized waste water effluent guidelines
R ₂	1979 EPA finalized waste water effluent guidelines	—	—
R ₃	—	—	—
X _{1i}	CSM	CAP	CSM
X _{2i}	Zinc and Copper production and imports	Zinc and Copper production and imports	Zinc and Copper production and imports
X _{3i}	Relative price of domestic Cd to imported Cd	Not relevant	Not relevant

CFC

Aerosols

Y_i CFC Aerosol consumption

U_i Soaps, detergents, and toiletries production index

PR₁ 1974 Univ. of Calif. Study (CFC-ozone depletion hypothesis)

PR₂ 1976 Intention for Rules

PR₃

PR₄

R₁

R₂

R₃

X_{1i}

X_{2i}

X_{3i}

1978 CFC aerosol ban by EPA and FDA

CAP

Production of carbon tetrachloride and chloroform

Not available

Refrigerants

CFC Refrigerant Production

Annual sales of refrigeration and air conditioning equipment

1974 Study

1977 EPA/FDA meeting

1980 ANPR

—

—

—

—

CAP

Production of carbon tetrachloride and chloroform

Not available

PERC

Dry Cleaning

PERC production and imports

Total solvents consumed in dry cleaning

1976 NIOSH recommen.

1971 NCI carcinogenity finding

1978 EPA emissions guidelines to assist states in regulating PERC

1979 CPSC finds PERC carcinogenic

—

—

—

CAP

Ethane and propane production (40%) and 35% ethylene dichloride production

Relative price of PERC to Stoddard Solvent

CHROMIUM

	<u>Pigments</u>	<u>Metal Treatment</u>	<u>Leather Tanning</u>
Y _i	Cr pigments production	Cr consumption in metal plating	Chromium consumption in Leather Tanning
U _i	Total synthetic inorganic pigment production	Total hours worked in plating industry	Leather products production index
PR ₁	1974 NAS study	1973 NIOSH plating plant studies	1974 NAS study
PR ₂	1975 NIOSH recommended new standard	1974 NAS study	1975 NIOSH recommended new standard
PR ₃	1978 OSHA proposed new standard	1976 EPA temporary effluent standard	1979 OSHA proposed new standard
PR ₄	—	1978 OSHA proposed new standard	—
R ₁	1971 ANSI and OSHA standards	1971 OSHA and ANSI standards	1971 OSHA and ANSI standards
R ₂	—	1979 EPA standard guidelines	—
R ₃	—	—	—
X _{1i}	CAP	CSM	CSM
X _{2i}	Total chromite ore imports (no domestic production)	Total chromite ore imports (no domestic production)	Total chromite ore imports (no domestic production)
X _{3i}	Not relevant	Not relevant	Not relevant

FORMALDEHYDE

	<u>UF Foam Insulation</u>	<u>Chelating Agents</u>
Y _i	UF Foam consumption	NTA consumption
U _i	Production or shipments of glass fiber and mineral insulation	All other chelating agent consumption
PR ₁	1978 studies/state action	1970 NCI found NTA carcinogenic
PR ₂	1979 CPSC consumer advisory	1971 Surgeon General Report
PR ₃	1980 CPSC proposed ban	—
PR ₄	—	—
R ₁	1982 CPSC ban	—
R ₂	—	—
R ₃	—	—
X _{1i}	CSM	CSM
X _{2i}	Total formaldehyde production (imports are negligible)	Total formaldehyde production (imports are negligible)
X _{3i}	Not available	Not available

NICKEL			
	<u>Nickel Alloys</u>	<u>Nickel Compounds</u>	<u>Electroplating</u>
Y _i	Nickel alloy steel production	Nickel consumption by the chemical industry	Consumption of nickel in electroplating
U _i	Steel mill products production index	Total inorganic compound production index	Total hours worked in the Electroplating and Polishing Industry
PR ₁	1975 NAS study	1974 ACGIH proposed Ni salt standard	1973 Cancer
PR ₂	1976 cancer reproted in alloy industry worker	1975 NAS Study	1974 ACGIH proposal
PR ₃	1977 NIOSH/OSHA events	1977 NIOSH/OSHA	1975 NAS Study
PR ₄	—	—	1977 NIOSH/OSHA
R ₁	1971 OSHA standard	1971 OSHA standard	1971 OSHA standard
R ₂	—	1976 ACGIH Ni salt standard	1976 ACGIH Ni salt standard
R ₃	—	—	—
X _{1i}	CSM	CSM	CSM
X _{2i}	Total U.S. nickel supply	Total U.S. nickel supply	Total U.S. nickel supply
X _{3i}	Not relevant	Not relevant	Not relevant (high overhead)

APPENDIX B
SUMMARY OF THE
ELEVEN MODEL SPECIFICATIONS

**SUMMARY OF THE
ELEVEN MODEL SPECIFICATIONS**

<u>Model Specification</u>	<u>Pre-Regulation (Suspect Hazard Designation)</u>	<u>Regulation</u>	<u>Economic Activity</u>	<u>Supply Feedstock</u>	<u>Price of Substitutes*</u>
#1	PR1	-	-	X1	X3
#2	-	PR2	-	X2	X3
#3	-	-	-	X2	X3
#4	-	-	R1	X2	X3
#5	PR1	PR2	-	X2	X3
#6	-	-	-	X2	X3
#7	PR1	-	R1	X2	X3
#8	PR1	PR2	-	X2	X3
#9	PR1	PR2	-	X2	X3
#10	PR1	PR2	R1	X2	X3
#11	PR1	PR2	R1	X2	X3

*Separate econometric modeling results were obtained for all eleven models with and without X3.

APPENDIX C

LEAD

	Chemicals	Pigments	Batteries
Y _i	Lead consumption in chemicals (tons, 100% Pb) (1965-81)	Lead consumption in pigments (tons, 100% Pb) (1965-81)	Lead consumption in batteries (tons 100% Pb) (1965-81)
U _i	Inorganic Chemicals and Fertilizer Materials Production Index	Total hours worked in inorganic pigment industry	Total hours worked in the Storage Batteries Industry
PR1	OSHA proposed 0.1 mg/m ³ lead exposure standard (1975)	OSHA proposed 0.1 mg/m ³ lead exposure standard (1975)	OSHA proposed 0.1 mg/m ³ lead exposure standard (1975)
PR2	EPA proposed 0.001 mg/m ³ lead air standard (1977)	EPA proposed hazardous waste management regs. for waste streams (1978)	EPA proposed hazardous waste management regs. for waste streams (1978)
PR3	EPA proposed hazardous waste management regs. for waste streams (1978)		
PR4			
R1	OSHA adopts ANSI lead standard (1971)	OSHA adopts ANSI lead standard (1971)	OSHA adopts ANSI lead standard (1971)
R2	EPA promulgated lead air standard; OSHA finalized new lead standard (1978)	CPSC publishes limit for lead in paint (1977)	OSHA finalized new lead standard (1978)
R3		OSHA finalized new lead standard (1978)	
R4			
X1 _i	CSM ¹	CAP ²	CSM
X2 _i	Total U.S. lead production (incl. imports and stocks)	Total lead production	Total lead production
X3 _i	Not available	Not available	Not available

¹ Federal Reserve Board's Chemical and Synthetic Materials (CSM) Index

² Federal Reserve Board's Chemical and Allied Products (CAP) Index

ASBESTOS

	Construction	Paper	Fibers
Y _i	Absolute asbestos consumption in construction applications (tons) (1965-80)	Asbestos consumption in paper (tons) (1965-80)	Asbestos consumption in fibers (tons) (1965-80)
U _i	Vinyl tile and flooring production (sq. ft.)	Construction paper production (tons)	Industrial & construction mineral insulation shipments (lbs.)
PR1	OSHA proposed 0.5 fiber/cc asbestos exposure standard (1972)	OSHA proposed 5 fiber/cc asbestos exposure standard (1972)	OSHA proposed 5 fiber/cc standard; FDA proposed rules for asbestos garments (1972)
PR2	EPA proposed rules for use of asbestos in construction	EPA proposed rules for use of asbestos in paper (1973)	OSHA proposed 0.5 fiber/cc standard (1975)
PR3	OSHA proposed 0.5 fiber/cc asbestos exposure standard (1975)	OSHA proposed 0.5 fiber/cc asbestos exposure standard (1975)	EPA and CPSC published ANPRs for non-essential asbestos uses (1979)
PR4	EPA & CPSC published ANPRs for non-essential asbestos uses (1979)	EPA & CPSC published ANPRs for non-essential asbestos uses (1979)	—
R1	OSHA finalized 12 fiber/cc standard; issues 5 fiber/cc emergency standard (1971)	OSHA finalized 5 fiber/cc standard (1972)	OSHA finalized 5 fiber/cc standard; FDA promulgated asbestos garment rules (1972)
R2	OSHA finalized 5 fiber/cc standard (1972)	EPA promulgated rules for use of asbestos in paper (1974)	OSHA finalized 2 fiber/cc standard (1976)
R3	EPA promulgated rules for use of asbestos in construction (1974)	OSHA finalized 2 fiber/cc standard (1976)	—
R4	OSHA finalized 2 fiber/cc standard (1976)	—	—
X1 _i	CSM	CSM	CSM
X2 _i	Total U.S. asbestos supply (Domestic mines + imports + stocks)	Total asbestos supply	Total asbestos supply
X3 _i	Not available	Not available	Not available

Polybrominated biphenyls (PBBs)		Polychlorinated biphenyls (PCBs)	
	<u>Flame Retardants</u>		<u>Electrical</u>
Y ₁	PBB production (lbs.) (1969-75)		Domestic PCB sales by Monsanto Co. (lbs.) (1965-78)
U ₁	Flame retardant plastics consumption of polyester resins (lbs.)		Electric Power and Industrial Equipment Production Index
PR ₁	Sole U.S. Producer of PBBs (Mich. Chem. Co.) stopped PBB production upon state request (1974)		Scientific investigations first confirmed presence of PCBs in the U.S. environment (1970)
PR ₂	-		Monsanto voluntarily discontinues PCB sales except for electrical applications (1971)
PR ₃	-		EPA proposes banning PCB discharges from PCB manufacturing plants (1976)
PR ₄	-		Monsanto ceased manufacture of PCBs (1977)
R ₁	FDA established permissible level guidelines for PBB in animal fat and animal feed (1974)		TSCA signed into law legislating ban on manufacture of PCBs (1976)
R ₂	-		EPA promulgated ban of PCB discharges by PCB manufacturers (1977)
R ₃	-		EPA promulgated labeling and disposal rules for PCBs (1978)
R ₄	-		-
X _{1i}	CAP		CAP
X _{2i}	Benzene production (gals.)		Benzene production (gals.)
X _{3i}	Not available		Not available

REFERENCES

1. AMAX Inc., "Removal of Metal Ions from Waste Water," U.S. Pat. 4,025,530, May 24, 1977.
2. American Conference of Governmental Industrial Hygienists, "Threshold Limit Values of Air-Borne Contaminants for 1968, Recommended and Intended Values," (Adapted at the 30th annual ACGIH meeting), May 13, 1968.
3. American Wood Preservers' Association, Wood Preservation Statistics 1981, November 1982, pp. 212, 223, 224.
4. Ashton and Crafts, Mode of Action of Herbicides, Chapter 10 - Arsenicals, John Wiley & Sons, Inc., New York, 1973, pp. 147-162.
5. Baumgartner, Robert, exec. ed; Predicasts Basebook, 1982 edition, Predicasts Inc., Cleveland, Ohio.
6. Booz, Allen & Hamilton, "Final Report: Review of the Economic Analysis of the Electroplating Industry, Phase I and Phase II," March 31, 1975.
7. Council on Environmental Quality, Federal Council for Science and Technology, "Fluorocarbons and the Environment; Report of the Federal Task Force on Inadvertent Modification of the Stratosphere (IMOS)," June 1975.
8. Department of the Environment, Central Directorate on Environmental Pollution, "Cadmium in the Environment and its Significance to Man," Pollution Paper No. 17, London, Her Majesty's Stationery Office, 1980.
9. Friberg, Lars, et al., Cadmium in the Environment, Second Edition, CRC Press, Inc., Cleveland, 1974.
10. Interagency Regulatory Liaison Group (CPSC, EPA, FDA, OSHA), Hazardous Substances, December, 1978.
11. Interagency Regulatory Liaison Group (CPSC, EPA, FDA, USDA, OSHA), Regulatory Reporter Vol. I, Issue 1, June 1979.
12. Interagency Regulatory Liaison Group (CPSC, EPA, FDA, USDA, OSHA), Regulatory Reporter, Volume II, Issue 1, July 1980.
13. Interagency Regulatory Liaison Group (CPSC, EPA, FDA, USDA, OSHA), Regulatory Reporter, Volume II, Issue II, December 1980.
14. Interagency Regulatory Liaison Group (CPSC, EPA, FDA, USDA, OSHA), Regulatory Reporter, Volume III, Issue 1, July 1981.
15. Kent, James, ed., Riegel's Handbook of Industrial Chemistry, Chapter 21 — The Pesticide Industry, 7th Edition, 1974, pp. 619-624.

16. Kirk-Othmer, eds., Encyclopedia of Chemical Technology, 3rd ed. Vols. 1-23, John Wiley & Sons, Inc., New York, 1978.
17. Lederer & Fensterheim, eds., Arsenic: Industrial, Biomedical, Environmental Perspectives, Van Nostrum & Reinholdt Co., New York, 1983, pp. 1-8, 63-65, 102.
18. Lowenheim, F.A., ed., Modern Electroplating, Chapter 12, John Wiley & Sons, Inc., New York, 1963.
19. Mannsville Chemical Products, "Chemical Products Synopsis — Perchloroethylene," Reporting Service, Aug. 1981.
20. Molina & Rowland, "Chlorofluoromethanes in the Environment," Reviews of Geophysics and Space Physics, 13, 1-35, 1975.
21. National Academy of Sciences, Chromium, Committee on Medical and Biological Effects of Environmental Pollutants, Washington, D.C., 1974.
22. National Academy of Sciences, Nickel, Committee on Medical and Biological Effects of Environmental Pollutants, Washington, D.C., 1975.
23. National Cotton Council of America, "Beltwide Cotton Production Research Conferences — 1980 Proceedings," James M. Brown, editor, pp. 194-200.
24. National Cotton Council of America, "Beltwide Cotton Production Research Conferences — 1981 Proceedings," James M. Brown, editor, pp. 179-184.
25. National Cotton Council of America, "Beltwide Cotton Production Research Conferences — 1982 Proceedings," James M. Brown, editor, pp. 249-253.
26. Nriagu, Jerome O., ed., Cadmium in the Environment, Part I: Ecological Cycling, John Wiley & Sons, Inc., New York, 1980.
27. Nriagu, Jerome O., ed., Nickel in the Environment, John Wiley & Sons, Inc., New York, 1980, pp. 4, 5, 52-63, 98, 99.
28. Roskill Information Services, Ltd., The Economics of Arsenic, 4th edition, 1982, pp. 15-25.
29. Schnell Publishing Company, Inc., "Chemical Profile — Perchloroethylene," Jan. 1, 1974; Jan. 15, 1977, and Oct. 1, 1979.
30. Stanford Research Institute, Chemical Economics Handbook.
31. Stoel, Thomas B. Jr., et al., Fluorocarbon Regulation: An International Comparison, Lexington Books, 1980.

32. U.S. Code of Federal Regulations, Chapter XVII — Occupational and Health Administration, Title 29, Section 1910.1000.
33. U.S. Consumer Product Safety Commission, "Briefing Package on Petition CP 79-1: Request of Artist Craftsmen of New York Inc., et al. to Ban Benzidine-Type Dyes," Washington, D.C., February 26, 1979.
34. U.S. Consumer Product Safety Commission, "Briefing Packages on Urea-Formaldehyde Foam Insulation," 1980 and 1982.
35. U.S. Consumer Product Safety Commission, "Briefing Package on Benzidine Congener Dyes," Chemical Hazards Program, Washington, D.C., April 4, 1983.
36. U.S. Department of Agriculture, "Quantities of Pesticides Used by Farmers in 1964," Agricultural Economics Report #131, Economic Research Service, Jan. 1968, pp. 16, 19.
37. U.S. Department of Agriculture, "Quantities of Pesticides Used by Farmers in 1966," Agricultural Economics Report #179, Economic Research Service, April 1970, pp. 12, 13, 35, 36.
38. U.S. Department of Agriculture, "Farmers' Use of Pesticides in 1971 — Quantities," Agricultural Economics Report #252, Economic Research Service, July 1974, pp. 9, 10, 30, 31.
39. U.S. Department of Agriculture, "Farmers' Use of Pesticides in 1976," Agricultural Economics Report #418, Economic Statistics Cooperative Service, December 1978, pp. 10, 35, 37.
40. U.S. Department of Energy, "Residential Energy Consumption Survey," 1980 and 1982.
41. U.S. Department of Health, Education, and Welfare, National Institute of Occupational Safety and Health, "NIOSH Criteria for a Recommended Standard . . . Occupational Exposure to Chromium (VI)," 1975.
42. U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, "NIOSH Criteria for a Recommended Standard . . . Occupational Exposure to Cadmium," HEW Publication No. (NIOSH) 76-192, August 1976.
43. U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, "NIOSH Criteria for a Recommended Standard . . . Occupational Exposure to Inorganic Nickel," Pub. No. 77-164, May 1977.
44. U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, "NIOSH Criteria for a Recommended Standard for Occupational Exposure to Acrylonitrile," 1978, Pub. No. 78-116.

45. U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health, "Special Occupational Hazard Review for Benzidine-Based Dyes," January 1980.
46. U.S. Department of Housing and Urban Development, Office of Assistant Secretary for Housing — Federal Housing Commissioner, "Manufactured Home Construction and Safety Standards; Proposed Revisions," Federal Register, v. 48, no. 159, pp. 37136, et seq., August 16, 1983.
47. U.S. Department of the Interior, Federal Water Pollution Control Administration, "Activated Sludge Treatment of Chrome Tannery Wastes," Water Pollution Control Research Series ORD-5, September 1969.
48. U.S. Department of the Interior, Bureau of Mines, Minerals in the U.S. Economy: Ten-Year Supply-Demand Profiles for Mineral and Fuel Commodities, 1974 and 1979 editions.
49. U.S. Department of the Interior, Bureau of Mines, "Regeneration and Recycling of Waste Chromic Acid—Sulfuric Acid Etchants," Report of Investigations 8377, 1979, 13 pp.
50. U.S. Department of the Interior, Bureau of Mines, Mineral Facts and Problems, Bulletin 671, 1980 edition.
51. U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook; Vol. I Metals and Minerals, 1981.
52. U.S. Department of the Interior, Bureau of Mines, Mineral Commodity Summaries, 1982 and 1983.
53. U.S. Department of Labor, Occupational Safety and Health Administration, "Final Report: Economic Impact Assessment for Acrylonitrile," Contract No. J-9-F-6-0229, Task 3, February 21, 1978.
54. U.S. Department of Labor (OSHA) and U.S. Department of Health and Human Services (NIOSH), "OSHA, NIOSH Health Hazard Alert: Benzidine-, o-Tolidine-, and o-Dianisidine-Based Dyes," Pub. No. DHHS (NIOSH) 81-106, December 1980.
55. U.S. Energy Research and Development Administration (ERDA), "Removal of Zn or Cd and Cyanide From Cyanide Electroplating Wastes," U.S. Pat. 4,026,790, May 31 1977.
56. U.S. Environmental Protection Agency, "An Investigation of Techniques for Removal of Chromium From Electroplating Wastes," #12010 EIE 03/71, (by Batelle Memorial Institute), March 1971, 91 pp.
57. U.S. Environmental Protection Agency, "Chemical Treatment of Plating Waste for Removal of Heavy Metals," (contractor report), EPA-R2-73-044, May 1973, 41 pp.

58. U.S. Environmental Protection Agency, "Chemical Technology and Economics in Environmental Perspectives, Task 1 — Technical Alternatives to Selected Chlorofluorocarbon Uses," PB-251, 146, (by the Midwest Research Insitute), February 1976.
59. U.S. Environmental Protection Agency, "Review of Existing Hydrocarbon Emission Regulations Applicable to Stationary Sources," Sub-task 6 of project plan for EPA Contract No. 68-02-1329, Task No. 9 (by the Dow Chemical Company), 1976.
60. U.S. Environmental Protection Agency, "Study to Support New Source Performance Standards for Solvent Metal Cleaning Operations — Appendix Reports," Contract No. 68-02-1329, Task Order No. 9 (by the Dow Chemical Company), June 30, 1976.
61. U.S. Environmental Protection Agency, "Control of Volatile Organic Emissions from Solvent Metal Cleaning," Research Triangle Park, Pub. No. PB-274 557, November 1977.
62. U.S. Environmental Protection Agency, "Source Assessment: Acrylonitrile Manufacture (Air Emissions)," Environmental Protection Technology Series, PB 271 969, September 1977.
63. U.S. Environmental Protection Agency, "Investigation of Selected Potential Environmental Contaminants: Acrylonitrile," (by the Franklin Institute Research Laboratories), Pub. No. PB-285 881/9, 1978.
64. U.S. Environmental Protection Agency, "PBI Reverse Osmosis Membrane for Chromium Plating Rinse Water," EPA Environmental Protection Technology Series, EPA-600/2-78-040, March 1978.
65. U.S. Environmental Protection Agency, "Evaporative Recovery of Chromium Plating Rinse Waters," (contractor report), EPA 600/2-78-127, June 1978, 42 pp.
66. U.S. Environmental Protection Agency, "Development of Standards of Performance for Solvent Metal Cleaning (Degreasing)," (draft document prepared by the Mitre Corp.), July 21, 1978.
67. U.S. Environmental Protection Agency, "Survey of the Manufacture, Import, and Uses for Benzidine, Related Substances, and Related Dyes and Pigments," PB 296 544, May 23, 1979.
68. U.S. Environmental Protection Agency, "Control of Volatile Organic Emissions from Perchloroethylene Dry Cleaning Systems," EPA Guideline Series, PB 290 613, December 1979.
69. U.S. Environmental Protection Agency, "Creosote, Inorganic Arsenicals, Pentachlorophenol—Wood Preservatives Position Document No. 2/3," January 1981, pp. 11-13.

70. U.S. Geological Survey, "Dispersal of Plating Wastes and Sewage Contaminants in Ground Water and Surface Water," USGS Water-Supply Paper 1879-G, 1970, 67 pp.
71. U.S. International Trade Commission, "Synthetic Organic Chemicals, United States Production and Sales," (published annually).
72. U.S. International Trade Commission, "Imports of Benzenoid Chemicals and Products," 1976-1981 editions, Washington, D.C.
73. U.S. International Trade Commission, "U.S. Synthetic Organic Dye Industry: Its Competitiveness in the World Market," USITC Pub. 1166, July 1981.
74. U.S. International Trade Commission, "Summary of Trade and Tariff Information, Synthetic Dyes," USITC Pub. 841, May 1982.
75. **List of Periodicals, as cited in text:**
 - a) Chemical and Engineering News
 - b) Chemical Business
 - c) Chemical Marketing Reporter
 - d) Chemical Week
 - e) Drug and Cosmetic Industry
 - f) Modern Packaging
 - g) Product Marketing
 - h) The Wall Street Journal